Nuytsia

WESTERN AUSTRALIAN HERBARIUM
VOLUME 34 2023

Department of **Biodiversity,
Conservation and Attractions**

GOVERNMENT OF
WESTERN AUSTRALIA

The cover photo for Volume 34 features a native bee (*Leioproctus* sp.) on *Leucopogon parviflorus* (Andrews) Lindl., photographed by Kate Brown in 2022 at the Albany wind farm.

Nuytsia

WESTERN AUSTRALIAN HERBARIUM

VOLUME 34 2023

DEPARTMENT OF BIODIVERSITY, CONSERVATION AND ATTRACTIONS
WESTERN AUSTRALIA

Nutysia

Nuytsia is an open access, peer-reviewed journal that publishes original research on the systematics, taxonomy and nomenclature of Australian (particularly Western Australian) plants, algae and fungi.

Descriptions of taxa, revisions, identification guides, nomenclatural and taxonomic issues, systematic analyses and classifications, censuses, and information on invasive species are all considered.

Published papers and information for authors can be downloaded from the *Nuytsia* website at https://florabase.dbca.wa.gov.au/nuytsia.

Enquiries regarding subscriptions and submissions should be addressed to:

The Managing Editor, *Nuytsia*
Email: nuytsia@dbca.wa.gov.au

Postal address:
Western Australian Herbarium
Biodiversity and Conservation Science
Department of Biodiversity, Conservation and Attractions
Locked Bag 104, Bentley Delivery Centre
Western Australia 6983

Editorial Committee

Managing Editor	Kelly Shepherd
Copy Editor	John Huisman
Editors	Benjamin Anderson John Huisman Shelley James Terry Macfarlane Juliet Wege
Production Editor	Kelly Shepherd
Curation	Amy Curtis Renee Gugiatti Cheryl Parker Julia Percy-Bower
Conservation	Tanya Llorens

Published by the Department of Biodiversity, Conservation and Attractions, Locked Bag 104, Bentley Delivery Centre, Western Australia 6983.

© Copyright of the Department of Biodiversity, Conservation and Attractions 2023. All material in this journal is copyright and may not be reproduced except with the written permission of the publishers.

ISSN 0085-4417 (print)

ISSN 2200-2790 (online)

The Western Australian Herbarium acknowledges the Traditional Owners of the land and waters from where our collections have come, and pays respect to their Elders past, present and emerging.

Nuytsia is produced on Whadjuk Noongar country.

Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF
WESTERN AUSTRALIA

CONTENTS

Updates to Western Australia's vascular plant census for 2022. J.M. Percy-Bower and C.M. Parker 1

Update to the taxonomy of *Hypocalymma* sect. *Hypocalymma* (Myrtaceae: Chamelaucieae), including hybrids and new species. G.J. Keighery, B.L. Rye & C. Tauss 21

Pterostylis segregata (Orchidaceae), a rare new species from south-west Western Australia. G. Brockman and C.J. French 61

Four new species of *Amanita* (Basidiomycota) from Western Australia. E.M. Davison, D. Giustiniano, M.D. Barrett and K. Syme 65

Lectotypification of *Astartea arbuscula* and *A. fascicularis* (Myrtaceae). J.A. Wege and B.L. Rye 93

Acacia armigera (Fabaceae), a new, geographically restricted wattle from the Coolgardie bioregion of Western Australia. K.R. Thiele, R.W. Davis and G.T.B. Cockerton 95

A new, geographically restricted species of *Acrotriche* (Ericaceae: Epacridoideae: Styphelieae) from the central south coast of Western Australia and an updated key to species. M. Hislop, K. Walkerden and J. Waters 99

George Maxwell's collecting locality – Eyre's Relief. L. Brooker 105

Amanita marinae (Basidiomycota), a new species from the mid-west region of Western Australia. E.M. Davison and D. Giustiniano 111

Taxonomic resolution of infraspecific taxa in *Lambertia orbifolia* (Proteaceae) using molecular and morphological evidence. J.A. Wege, L.T. Monks, A.D. Webb, R.M. Binks and D.J. Coates 125

The taxonomy of the *Styphelia corynocarpa* subgroup (Ericaceae: Epacridoideae: Styphelieae). M. Hislop 139

Ferdinand Mueller in Western Australia in 1877, with notes on his later contributions to the Western Australian flora. J.L. Dowe 157

Echinostelium australiense (Myxomycetes: Echinosteliaceae), a new species of slime mould described from Western Australia. K.J. Knight, S.L. Stephenson and Y.K. Novozhilov 179

Volvopluteus earlei and *Volvariella taylorii*: new fungi for Western Australia (Basidiomycota: Agaricales: Pluteaceae). N.L. Bougher and M.D. Barrett 187

Marasmius australotrichotus (Marasmiaceae), a new setose species from Australia, and an intriguing range extension for *M. paratrichotus*. F.E. Guard, J. Dearnaley, T. Lebel, M.D. Barrett and N.L. Bougher 203

Molecular analysis identifies a red seaweed common in the Swan Estuary as *Gracilaria transtasmanica* (Gracilariales: Gracilariaceae). J.M. Huisman, G.C. Zuccarello and S.-M. Lin 221

Revision of the connate bract group allied to *Goodenia panduriformis* (Goodeniaceae), including recognition of three new species. K.A. Shepherd & B.J. Lepschi 227

Eremophila improvisa, *E. rubicunda* and *E. saxatilis* (Scrophulariaceae), three new species from Western Australia. A.P. Brown and R.W. Davis 255

Four new species of *Triodia* (Poaceae) from the Pilbara and adjacent bioregions, Western Australia. M.D. Barrett, P.-L. de Kock and S.J. Dillon 261

Corrigendum to: *Marasmius australotrichotus* (Marasmiaceae), a new setose species from Australia, and an intriguing range extension for *M. paratrichotus*. F.E. Guard, J. Dearnaley, T. Lebel, M.D. Barrett and N.L. Bougher 295

Other content

Referees for Volume 34 299

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 1–20
https://doi.org/10.58828/nuy01043 Published online 21 March 2023

Updates to Western Australia's vascular plant census for 2022

Julia M. Percy-Bower[1] and Cheryl M. Parker

Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[1]Corresponding author, email: julia.percy-bower@dbca.wa.gov.au

SHORT COMMUNICATION

The census database at the Western Australian Herbarium (PERTH), which provides the nomenclature for the website *Florabase* (Western Australian Herbarium 1998–), lists current names and recent synonymy for Western Australia's native and naturalised vascular plants, as well as algae, bryophytes, lichens, slime moulds and some fungi. The names represented in the census are either sourced from published research or denote as yet unpublished names based on herbarium voucher specimens. We herein summarise the changes made to vascular plant names in this database during 2022.

Eighty-three taxa were newly recorded for the State, of which eight are naturalised and 20 have been added to the Threatened and Priority Flora list for Western Australia (State of Western Australia 2022; Western Australian Herbarium 1998–) (Table 1). A total of 261 name changes were made, including the formal publication of 68 phrase-named taxa (Table 2). Table 2 also includes cases where there has been a change of taxonomic concept, misapplication, exclusion or rank change. Plant groups for which several name changes were made include *Styphelia* Sm. (Hislop 2021, 2022; Hislop & Nguyen 2022), *Euploca* Nutt. (Frohlich *et al.* 2020; Hilger & Diane 2003), *Austrostipa* S.W.L.Jacobs & J.Everett (Williams 2022) and *Eucalyptus* L'Her. (Nicolle & French 2021). A number of new taxa were formally published in *Grevillea* Knight (Olde 2022a, 2022b), as well as a revision of the *Grevillea thelemanniana* group (Olde & Keighery 2022). Numerous phrase-named taxa in the genus *Baeckea* L. were formally published under *Austrobaeckea* Rye and *Balaustion* Hook. (Rye 2021, 2022), and a significant revision in the classification of Phyllanthaceae Martinov resulted in the transfer of numerous *Phyllanthus* L. to other genera (Bouman *et al.* 2022).

Table 1. New records added to Western Australia's vascular plant census during 2022. *in litt.* = in correspondence; *in sched.* = on herbarium sheet/label; * = naturalised; T, P1–P4 = Department of Biodiversity, Conservation and Attractions Conservation Codes for Western Australian flora (State of Western Australia 2022; Western Australian Herbarium 1998–).

New Name	Status	Comments
Actinotus paddisonii R.T.Baker		New record for WA. A.J. Perkins *in litt.* (19/05/2022).
Azanza thespesioides var. *flaviflora* (F.Muell.) F.Areces		See Areces-Berazain & Ackerman (2020).

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

New Name	**Status**	**Comments**
Barleria obtusa Nees	*	New naturalised record for WA. M. Langley *in litt.* (28/04/2022).
Calandrinia sp. Bayswater (C. Andrews s.n. 11/1902)	P1	F. Obbens *in litt.* (28/03/2022).
Calandrinia sp. Lennard River (W.V. Fitzgerald 739)	P1	F. Obbens *in litt.* (28/03/2022).
Calandrinia sp. Mt Vernon Station (T.L. Setter 427)	P1	F. Obbens *in litt.* (21/04/2022)
Calytrix calingiri Nge & K.R.Thiele	P3	See Nge & Thiele (2022).
Calytrix mucronulata K.R.Thiele		See Thiele *et al.* (2022).
Calytrix ryeae K.R.Thiele		See Thiele *et al.* (2022).
Causonis maritima (Jackes) Jackes		New record for WA. See Parmar *et al.* (2021).
Conostephium wonganense Hislop	P1	See Hislop (2022).
Conostylis sp. Watheroo (S.D. Hopper 7668)	P2	M. Hislop *in litt.* (29/03/2022).
Dianella lignosa R.L.Barrett & M.D.Barrett		See Barrett & Barrett (2022).
Dielsiodoxa altimontana Hislop	P2	See Hislop (2022).
Dinebra retroflexa Panz.	*	New naturalised record for WA. M. Hislop *in litt.* (06/12/2022).
Drosera sp. Yampi Peninsula (A.J.M. Hopkins BA 0248)	P1	T. Krueger & A. Fleischmann *in litt.* (10/06/2022).
Eragrostis eriopoda subsp. Hill top (P.K. Latz 11583)		P. Latz *in sched.* (19/08/2016).
Eragrostis eriopoda subsp. Sandy fireweed (P.K. Latz 12908)		P. Latz *in sched.* (19/08/2016).
Eragrostis sp. Lake Carey (J. Paterson & J. Warden WB 40825)	P1	J. Paterson *in litt.* (24/02/2022).
Eucalyptus connexa D.Nicolle & M.E.French		See Nicolle & French (2021).
Eucalyptus foecunda Schauer subsp. *foecunda*	P4	See Nicolle & French (2021).
Eucalyptus formanii subsp. *circulata* D.Nicolle & M.E.French	P4	See Nicolle & French (2021).
Eucalyptus formanii C.A.Gardner subsp. *formanii*	P4	See Nicolle & French (2021).
Eucalyptus rigidula subsp. *interior* D.Nicolle & M.E.French		See Nicolle & French (2021).
Eucalyptus uncinata Turcz. subsp. *uncinata*		See Nicolle & French (2021).
Euphorbia ferdinandi var. *appendiculata* Halford & W.K.Harris		New record for WA. M. Hislop *in litt.* (30/03/2022).
Grevillea sp. Nyabing (A. Coates & J. Ward AC 6030)	P1	R. Davis *in litt.* (01/07/2022).

New Name	Status	Comments
Helosciadium nodiflorum (L.) W.D.J.Koch	*	New naturalised record for WA. G.J. Keighery *in litt.* (19/05/2022).
Hibbertia archeri T.Hammer & K.R.Thiele	P1	See Hammer & Thiele (2022).
Hibbertia subvillosa (Domin) K.R.Thiele & T.Hammer		See Thiele & Hammer (2022).
Hibbertia sp. Bendering (J.W. Horn 4101)	P1	K.R. Thiele *in litt.* (14/11/2022).
Hibbertia sp. Dragon Rocks (A.M. Coates 2875)	P2	K.R. Thiele *in litt.* (14/11/2022).
Hibbertia sp. Frank Hann (K. Newbey 10900)	P2	K.R. Thiele *in litt.* (14/11/2022).
Hibbertia sp. Mount Gibbs (G.F. Craig 6668-1)	P2	K.R. Thiele *in litt.* (14/11/2022).
Hibbertia sp. Mount Gibson (B.H. Smith 883)	P1	K.R. Thiele *in litt.* (14/11/2022).
Homalanthus populifolius Graham	*	New naturalised record for WA. See Keighery & Mitchell (2022).
Hyparrhenia rufa (Nees) Stapf	*	New naturalised record for WA. G.J. Keighery *in litt.* (06/06/2022).
Ischaemum decumbens Benth.		New record for WA. M. Hislop *in litt.* (30/03/2022).
Kunzea affinis S.Moore × *Kunzea jucunda* Diels		See Toelken (1996).
Kunzea cincinnata Toelken × *Kunzea jucunda* Diels		See Toelken (1996).
Kunzea clavata Toelken × *Kunzea ericifolia* (Sm.) Heynh. subsp. *ericifolia*		See Toelken (1996).
Kunzea clavata Toelken × *Kunzea recurva* Schauer		See Toelken (1996).
Kunzea ericifolia (Sm.) Heynh. subsp. *ericifolia* × *Kunzea recurva* Schauer		See Toelken (1996).
Kunzea glabrescens Toelken × *Kunzea recurva* Schauer		See Toelken (1996).
Kunzea jucunda Diels × *Kunzea preissiana* Schauer		See Toelken (1996).
Kunzea micrantha subsp. *oligandra* (Turcz.) Toelken × *Kunzea micromera* Schauer		See Toelken (1996).
Kunzea micrantha subsp. *oligandra* (Turcz.) Toelken × *Kunzea recurva* Schauer		See Toelken (1996).
Kunzea micrantha subsp. *petiolata* Toelken × *Kunzea praestans* Schauer		See Toelken (1996).
Kunzea micromera Schauer × *Kunzea montana* (Diels) Domin		See Toelken (1996).
Kunzea micromera Schauer × *Kunzea preissiana* Schauer		See Toelken (1996).
Kunzea micromera Schauer × *Kunzea recurva* Schauer		See Toelken (1996).
Kunzea montana (Diels) Domin × *Kunzea recurva* Schauer		See Toelken (1996).

New Name	Status	Comments
Kunzea recurva Schauer × *Kunzea sulphurea* Tovey & P.Morris		See Toelken (1996).
Lambertia orbifolia subsp. Bowelling (A. Webb AW 09107)	P2	J.A. Wege *in litt.* (27/07/2022).
Linaria pelisseriana (L.) Mill.	*	New naturalised record for WA. M. Hislop *in sched.* (13/09/2022).
Lindernia sp. Theda (R.L. Barrett & M.D. Barrett RLB 3220)		M.D. Barrett *in litt.* (08/11/2022).
Lycianthes rantonnetii (Carriere) Bitter	*	New naturalised record for WA. See Knapp (2022).
Microcorys sp. Great Victoria Desert (J. Alford s.n. PERTH 09041567)	P2	M. Hislop *in litt.* (29/11/2021).
Mitracarpus hirtus (L.) DC.	*	New naturalised record for WA. M. Hislop pers. comm. (16/03/2022).
Murdannia sp. Top End (G.M. Chippendale 7726)	P1	M.D. Barrett *in litt.* (28/01/2021).
Neptunia heliophila A.R.Bean		See Bean (2022).
Neptunia longipila A.R.Bean		See Bean (2022).
Neptunia scutata A.R.Bean		See Bean (2022).
Neptunia tactilis A.R.Bean		See Bean (2022).
Neptunia valida A.R.Bean		See Bean (2022).
Neptunia xanthonema A.R.Bean		See Bean (2022).
Nicotiana bilybara M.W.Chase & Christenh.		See Chase *et al.* (2022).
Nicotiana candelabra M.W.Chase & Christenh.		See Chase *et al.* (2022).
Nicotiana rupestris M.W.Chase & Christenh.		See Chase *et al.* (2022).
Ornduffia reniformis (R.Br.) Tippery & Les		New record for WA. A. Markey *in litt.* (22/11/2022).
Pandorea pandorana (Andrews) Steenis subsp. *pandorana*		New record for WA. G. Keighery *in litt.* (16/12/2021).
Portulaca sp. Berkeley River (M.D. Barrett MDB 4766)		M.D. Barrett *in litt.* (09/09/2022).
Portulaca sp. finely echinate (D.G. Tulloch 41)		M.D. Barrett *in litt.* (09/09/2022).
Portulaca sp. Kongorow Pool (M.D. Barrett & K.W. Dixon MDB 4556)		M.D. Barrett *in litt.* (09/09/2022).
Portulaca sp. Morgan River (M.D. Barrett 1549)		M.D. Barrett *in litt.* (09/09/2022).
Portulaca sp. Theda Station (R.L. Barrett & M.D. Barrett RLB 3285)		M.D. Barrett *in litt.* (09/09/2022).
Solanum sp. W Hamersley Range (S. Colwill & B. Duncan LCR99-01)	P1	M. Hislop *in litt.* (22/03/2022).

New Name	**Status**	**Comments**
Stackhousia muricata subsp. Perennial (W.R. Barker 3641)	P3	See Barker *et al.* (2005).
Stylidium milleri Wege	P2	See Wege (2022).
Styphelia madida subsp. *hirtigera* Hislop		See Hislop (2021).
Styphelia madida Hislop subsp. *madida*		See Hislop (2021).
Terminalia erythrocarpa F.Muell.		New record for WA. M. Hislop *in sched.* (07/12/2022).
Xerochrysum wilsonii T.L.Collins		See Collins *et al.* (2022).

Table 2. Changes to existing entries in Western Australia's vascular plant census during 2022. Excluded taxon = a name used in the botanical literature that refers to a taxon never occurring in WA; misapplied name = a name used in the botanical literature but now considered to refer to one or more different WA taxa; nomenclatural synonym = a superseded name based on the same type specimen as the accepted name; taxonomic synonym = a superseded name based on a different type specimen to the accepted name; orthographic variant = mis-spelling of a name in original publication; *in litt.* = in correspondence; *in sched.* = on herbarium sheet/label; *p.p.* = in part. Status: * = naturalised; T, P1–P4 = Department of Biodiversity, Conservation and Attractions Conservation Codes for Western Australian flora (State of Western Australia 2022; Western Australian Herbarium 1998–).

Old Name	**New Name**	**Status**	**Comments**
Acacia thoma Maslin	*Acacia thomae* Maslin		Orthographic variant. See George & Sharr (2021).
Acacia wickhamii subsp. *cassitera* (Pedley) Tindale & Kodela	*Acacia wickhamii* subsp. *cassiterum* (Pedley) Tindale & Kodela		Orthographic variant. See George & Sharr (2021).
Astroloma sp. Grass Patch (A.J.G. Wilson 110)	*Stenanthera lacsalaria* A.J.G.Wilson & Hislop	P1	Taxon formally published. See Hislop & Wilson (2022).
Austrostipa bronwenae A.R.Williams	*Austrostipa bronweniae* A.R.Williams	T	Orthographic variant. See George & Sharr (2021).
Austrostipa sp. Cairn Hill (M.E. Trudgen 21176)	*Austrostipa nunaginensis* A.R.Williams	P3	Taxon formally published. See Williams (2022).
Austrostipa sp. Carlingup Road (S. Kern & R. Jasper LCH 18459)	*Austrostipa turbinata* A.R.Williams	P3	Taxon formally published. See Williams (2022).
Austrostipa sp. Dowerin (G. Wiehl F 8004)	*Austrostipa frankliniae* A.R.Williams	P2	Taxon formally published. See Williams (2022).
Austrostipa sp. Koorda (Anonymous s.n. PERTH 08730202)	*Austrostipa koordana* A.R.Williams	P1	Taxon formally published. See Williams (2022).
Austrostipa sp. Marchagee (B.R. Maslin 1407)	*Austrostipa anaiwaniorum* A.R.Williams		Taxon formally published. See Williams (2022).
Austrostipa sp. Mt Burgess (A.A. Mitchell & P.J. Waddell 10499)	*Austrostipa burgesiana* A.R.Williams	P1	Taxon formally published. See Williams (2022).

Old Name	New Name	Status	Comments
Austrostipa sp. Mt Holland (W.A. Thompson & J. Allen 948)	*Austrostipa everettiana* A.R.Williams	P1	Taxon formally published. See Williams (2022).
Austrostipa sp. Ravensthorpe Range (A. Markey & J. Allen 6261)	*Austrostipa heteranthera* A.R.Williams	P2	Taxon formally published. See Williams (2022).
Baeckea exserta S.Moore	*Balaustion exsertum* (S.Moore) Rye	P3	Nomenclatural synonym. See Rye (2022).
Baeckea grandibracteata E.Pritz.	*Balaustion grandibracteatum* (E.Pritz.) Rye		Nomenclatural synonym. See Rye (2022).
Baeckea grandibracteata subsp. Parker Range (K.R. Newbey 9270)	*Balaustion grandibracteatum* subsp. *grandibracteatum* (E.Pritz.) Rye	P3	Name synonymised. See Rye (2022).
Baeckea grandis E.Pritz.	*Balaustion grande* (E.Pritz.) Rye	P3	Nomenclatural synonym. See Rye (2022).
Baeckea latens C.R.P.Andrews	*Austrobaeckea latens* (C.R.P.Andrews) Rye		Nomenclatural synonym. See Rye (2021).
Baeckea pachyphylla Benth.	*Austrobaeckea pachyphylla* (Benth.) Rye		Nomenclatural synonym. See Rye (2021).
Baeckea pygmaea Benth.	*Austrobaeckea pygmaea* (Benth.) Rye		Nomenclatural synonym. See Rye (2021).
Baeckea uncinella Benth.	*Austrobaeckea uncinella* (Benth.) Rye	P3	Nomenclatural synonym. See Rye (2021).
Baeckea sp. Baladjie (P.J. Spencer 24)	*Balaustion spenceri* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Beringbooding (A.R. Main 11/9/1957)	*Balaustion filifolium* Rye	P2	Taxon formally published. See Rye (2022).
Baeckea sp. Billyacatting Hill (A.S. George 14349)	*Balaustion* sp. Billyacatting Hill (A.S. George 14349)	P2	Name synonymised. See Rye (2022).
Baeckea sp. Blue Haze Mine (P. Armstrong 06/910)	*Balaustion grandibracteatum* subsp. *juncturum* Rye	P2	Name synonymised. See Rye (2022).
Baeckea sp. Burakin (M.E. & M.E. Trudgen 1423)	*Balaustion interruptum* Rye		Taxon formally published. See Rye (2022).
Baeckea sp. Corackerup (K.R. Newbey 5048)	*Austrobaeckea columnaris* Rye	P2	Taxon formally published. See Rye (2021).
Baeckea sp. Crossroads (B.L. Rye & M.E. Trudgen 241186)	*Balaustion grandibracteatum* subsp. *juncturum* Rye	P2	Name synonymised. See Rye (2022).
Baeckea sp. Diemals (A.P. Brown 3636)	*Balaustion tangerinum* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Elsewhere Road (M.E. Trudgen 5420)	*Balaustion mukinbudin* Rye	P3	Taxon formally published. See Rye (2022).
Baeckea sp. Esperance (A.G. Gunness AG 2435)	*Austrobaeckea fascifolia* Rye		Taxon formally published. See Rye (2021).
Baeckea sp. Eujinyn (J. Buegge D 99)	*Balaustion exsertum* (S.Moore) Rye	P3	Name synonymised. See Rye (2022).
Baeckea sp. Forrestania (K.R. Newbey 1105)	*Balaustion grandibracteatum* subsp. *juncturum* Rye	P2	Name synonymised. See Rye (2022).
Baeckea sp. Hatter Hill (K.R. Newbey 3284)	*Balaustion thamnoides* Rye	P2	Taxon formally published. See Rye (2022).

Old Name	New Name	Status	Comments
Baeckea sp. Jaurdi Station (L.W. Sage & F. Hort 2229)	*Balaustion polyandrum* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Kellerberrin (C.A. Gardner s.n. PERTH 03351009)	*Balaustion exsertum* (S.Moore) Rye	P3	Name synonymised. See Rye (2022).
Baeckea sp. Koonadgin (B.L. Rye & M.E. Trudgen BLR 241137)	*Balaustion quinquelobum* Rye		Name synonymised. See Rye (2022).
Baeckea sp. Koorda (W.E. Blackall 3371)	*Balaustion baiocalyx* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Lake Cronin (K.R. Newbey 9191)	*Balaustion* sp. North Ironcap (R.J. Cranfield 10580)	P1	Name synonymised. See Rye (2022).
Baeckea sp. Mt Gibbs (G.F. Craig 7031)	*Balaustion grandibracteatum* subsp. *meridionale* Rye	P2	Name synonymised. See Rye (2022).
Baeckea sp. Mt Glasse (P.G. Wilson 5717)	*Balaustion grandibracteatum* subsp. *meridionale* Rye	P2	Name synonymised. See Rye (2022).
Baeckea sp. Muntadgin (E.T. Bailey 231)	*Balaustion quinquelobum* Rye		Name synonymised. See Rye (2022).
Baeckea sp. Narembeen (G.J. Keighery & N. Gibson 3010)	*Austrobaeckea narembeen* Rye	P2	Taxon formally published. See Rye (2021).
Baeckea sp. North Ironcap (R.J. Cranfield 10580)	*Balaustion* sp. North Ironcap (R.J. Cranfield 10580)	P1	Name synonymised. See Rye (2022).
Baeckea sp. Sheoaks Rocks (M.E. Trudgen MET 5452)	*Balaustion multicaule* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Stockton Road (M.E. Trudgen MET 22077 & B.L. Rye)	*Balaustion bimucronatum* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Tammin (R. Coveny 8319 & B. Habberley)	*Balaustion exsertum* (S.Moore) Rye	P3	Name synonymised. See Rye (2022).
Baeckea sp. Tampia Hill (J.C. Anway 327)	*Balaustion exsertum* (S.Moore) Rye	P3	Name synonymised. See Rye (2022).
Baeckea sp. Wialki (G.M. Storr s.n. 4/10/1958)	*Balaustion karroun* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Yacke Yackine Dam (K.R. Newbey 9195)	*Balaustion unguiculatum* Rye	P1	Taxon formally published. See Rye (2022).
Baeckea sp. Yorkrakine (C.A. Gardner s.n. 09/1933)	*Balaustion* sp. Yorkrakine (C.A. Gardner s.n. 09/1933)	P1	Name synonymised. See Rye (2022).
Banksia seminuda subsp. *remanens* Hopper	n/a		Name made current. Taxon reinstated. See Robins *et al.* (2021).
Banksia seminuda A.S.George subsp. *seminuda*	n/a		Name made current. Taxon reinstated. See Robins *et al.* (2021).
Bauhinia cunninghamii (Benth.) Benth.	*Lysiphyllum cunninghamii* (Benth.) de Wit		Nomenclatural synonym. See Sinou *et al.* (2020).
Bauhinia malabarica Roxb.	*Piliostigma malabaricum* (Roxb.) Benth.		Nomenclatural synonym. See Sinou *et al.* (2020).
Bidens pilosa var. *minor* (Blume) Sherff	*Bidens pilosa* L.	*	Taxonomic synonym. See Bean (2020).

Old Name	**New Name**	**Status**	**Comments**
Bidens pilosa L. var. *pilosa*	*Bidens pilosa* L.	*	Nomenclatural synonym. See Bean (2020).
Bidens subalternans DC.	*Bidens bipinnata* L.	*	Misapplied name. See Bean (2020).
Bidens subalternans var. *araneosa* Orchard	*Bidens bipinnata* L.	*	Taxonomic synonym. See Bean (2020).
Bidens subalternans var. *simulans* Sherff	*Bidens bipinnata* L.	*	Misapplied name. See Bean (2020).
Bidens subalternans DC. var. *subalternans*	*Bidens bipinnata* L.	*	Misapplied name. See Bean (2020).
Brachyloma ericoides (Schltdl.) Sond.	n/a		Excluded taxon. This taxon does not occur in WA. M. Hislop *in litt.* (29/07/2022).
Caladenia longicauda subsp. *rigidula* Hopper & A.P.Br.	*Caladenia longicauda* subsp. *rigidulus* Hopper & A.P.Br.		Orthographic variant. See George & Sharr (2021).
Caladenia lorea Hopper & A.P.Br.	*Caladenia loreus* Hopper & A.P.Br.		Orthographic variant. See George & Sharr (2021).
Calandrinia creethiae Morrison	*Calandrinia creethae* Morrison		Orthographic variant. See CHAH (2006).
Calochilus sp. A Kimberley Flora (K.F. Kenneally 7110)	*Calochilus kimberleyensis* R.L.Barrett, M.D.Barrett & K.W.Dixon		Taxon formally published. See Barrett *et al.* (2022).
Calochilus sp. Theda (R.L. Barrett *et al.* RLB 6158)	*Calochilus barbarossa* R.L.Barrett, M.D.Barrett & K.W.Dixon		Name synonymised. See Barrett *et al.* (2022).
Calytrix platycheiridia Craven	*Calytrix platycheiridion* Craven	P2	Orthographic variant. See George & Sharr (2021).
Calytrix sp. Cape Riche (G.J. Keighery & B.J. Keighery 2934)	*Calytrix djinda* Keighery & Rye	P1	Taxon formally published. See Thiele *et al.* (2022).
Carissa spinarum L.	*Carissa lanceolata* R.Br.		Misapplied name *p.p.* See CHAH (2021a).
Carissa spinarum L.	*Carissa ovata* R.Br.		Misapplied name *p.p.* See CHAH (2021b).
Convolvulus sp. Cascades (W. Archer 1110161)	*Convolvulus pyrophilus* O.Nazarova & Hislop	P1	Taxon formally published. See Nazarova & Hislop (2021).
Corynanthera flava J.W.Green	*Micromyrtus flava* (J.W.Green) Rye & Peter G.Wilson		Nomenclatural synonym. See Rye & Wilson (2022).
Cuphonotus andraeanus (F.Muell.) E.A.Shaw	*Lemphoria andraeana* (F.Muell.) Al-Shehbaz & Lysak		Nomenclatural synonym. See Lysak *et al.* (2022).
Cuphonotus humistratus (F.Muell.) O.E.Schulz	*Lemphoria humistrata* (F.Muell.) Al-Shehbaz & Lysak	P1	Nomenclatural synonym. See Lysak *et al.* (2022).
Cylindropuntia rosea (DC.) Backeb.	*Cylindropuntia imbricata* subsp. *rosea* (DC.) M.A.Baker	*	Nomenclatural synonym. See Baker *et al.* (2019).
Dampiera sp. Jurien (G. Lullfitz s.n. 10/7/1986)	*Dampiera tephrea* Rajput & Carolin	P3	Name synonymised. M. Hislop *in sched.* (29/03/2022).
Dipodium sp. Basalt Woodland (M.D. Barrett 198)	*Dipodium basalticum* M.D.Barrett, R.L.Barrett & K.W.Dixon	P1	Taxon formally published. See Barrett *et al.* (2022).

Old Name	**New Name**	**Status**	**Comments**
Dipodium sp. Sandstone (R.L. Barrett & K.W. Dixon RLB 1642)	*Dipodium ammolithum* M.D.Barrett, R.L.Barrett & K.W.Dixon		Taxon formally published. See Barrett *et al.* (2022).
Dipodium stenocheilum O.Schwarz	*Dipodium basalticum* M.D.Barrett, R.L.Barrett & K.W.Dixon	P1	Misapplied name. See Barrett *et al.* (2022).
Diuris carecta D.L.Jones & C.J.French	*Diuris carectum* D.L.Jones & C.J.French		Orthographic variant. See George & Sharr (2021).
Drummondita sp. Trayning (A.M. George 97)	*Drummondita billyacatting* L.R.J.Shelton & K.R.Thiele	P2	Taxon formally published. See Shelton & Thiele (2022).
Eremophila xantholaema R.W.Davis	*Eremophila xantholaemus* R.W.Davis	P1	Orthographic variant. See George & Sharr (2021).
Eremophila sp. Calvert Range (A.A. Burbidge 738)	*Eremophila hurteri* A.L.Curtis & K.R.Thiele		Taxon formally published. See Curtis *et al.* (2022).
Eremophila sp. Hamersley Range (K. Walker KW 136)	*Eremophila naaykensii* A.L.Curtis & K.R.Thiele	P3	Taxon formally published. See Curtis *et al.* (2022).
Eremophila sp. Rudall River (P.G. Wilson 10512)	*Eremophila tietkensii* F.Muell. & Tate		Name synonymised. See Curtis *et al.* (2022).
Eriochilus sp. Roleystone (G. Brockman 1140)	*Eriochilus glareosus* G.Brockman & C.J.French	P1	Taxon formally published. See Brockman & French (2022).
Eucalyptus goniantha subsp. *kynoura* D.Nicolle & M.E.French	*Eucalyptus goniantha* subsp. *kynouron* D.Nicolle & M.E.French	P2	Orthographic variant. See George & Sharr (2021).
Eucalyptus grasbyi Maiden & Blakely	n/a		Name made current. Taxon reinstated. See Nicolle (2021).
Eucalyptus leptophylla Miq.	n/a		Excluded taxon. This taxon does not occur in WA. See Nicolle & French (2021).
Eucalyptus leptophylla var. *floribunda* Blakely	*Eucalyptus efflorescens* D.Nicolle & M.E.French	P1	Taxonomic synonym. See Nicolle & French (2021).
Eucalyptus sp. Fraser Range (D. Nicolle 2157)	*Eucalyptus rigidula* subsp. *clancularia* D.Nicolle & M.E.French		Taxon formally published. See Nicolle & French (2021).
Eucalyptus sp. Great Victoria Desert (D. Nicolle & M. French DN 3877)	*Eucalyptus ecdysiastes* D.Nicolle & M.E.French		Name synonymised *p.p.* See Nicolle & French (2021).
Eucalyptus sp. Great Victoria Desert (D. Nicolle & M. French DN 3877)	*Eucalyptus omissa* D.Nicolle & M.E.French		Name synonymised *p.p.* See Nicolle & French (2021).
Eucalyptus sp. Kalbarri (M.I.H. Brooker 7937)	*Eucalyptus rigidula* Maiden subsp. *rigidula*		Name synonymised. See Nicolle & French (2021).
Eucalyptus sp. Mt Short (D. Nicolle & M. French DN 3575)	*Eucalyptus uncinata* subsp. *crassifolia* D.Nicolle & M.E.French	P2	Taxon formally published. See Nicolle & French (2021).
Eucalyptus sp. Mulga Rock (K.D. Hill & L.A.S. Johnson KH 2668)	*Eucalyptus plumula* D.Nicolle & M.E.French		Name synonymised. See Nicolle & French (2021).
Eucalyptus sp. Ravensthorpe (A.S. George 616)	*Eucalyptus austrina* D.Nicolle & M.E.French		Taxon formally published. See Nicolle & French (2021).

Old Name	New Name	Status	Comments
Eucalyptus sp. Southern smooth-bark (D. Nicolle & M. French DN 6916)	*Eucalyptus ecdysiastes* D.Nicolle & M.E.French		Name synonymised. See Nicolle & French (2021).
Eucalyptus sp. Sullivan Soak (D. Nicolle & M. French DN 5503)	*Eucalyptus lunata* D.Nicolle & M.E.French		Taxon formally published. See Nicolle & French (2021).
Eucalyptus sp. Truslove (M.I.H. Brooker 7499)	*Eucalyptus dissimulata* subsp. *plauta* D.Nicolle & M.E.French	P1	Taxon formally published. See Nicolle & French (2021).
Eulophia venosa (F.Muell.) Benth.	*Eulophia bicallosa* (D.Don) P.F.Hunt & Summerh.	P3	Misapplied name. See Barrett *et al.* (2022).
Exocarpos sp. Ardath (J. Buegge D 62)	*Exocarpos capnodioides* Lepschi		Taxon formally published. See Lepschi (2022).
Geodorum densiflorum (Lam.) Schltr.	*Eulophia picta* (R.Br.) Ormerod		Taxonomic synonym. See Naive *et al.* (2022).
Gilesia biniflora F.Muell.	n/a		Name made current. Taxon reinstated as occurring in WA. M. Hislop *in sched.* (19/10/2021).
Gonocarpus benthamii subsp. Stirling (C.J. Robinson 1080)	*Gonocarpus benthamii* Orchard		Name synonymised. Subspecies not recognised. M. Hislop *in litt.* (31/12/2021).
Goodenia holtzeana (Specht) Carolin	n/a		Name made current. Taxon reinstated as occurring in WA. M. Hislop *in litt.* (30/03/2022).
Grevillea bronwenae Keighery	*Grevillea bronweniae* Keighery	P3	Orthographic variant. See George & Sharr (2021).
Grevillea manglesii subsp. *dissectifolia* (McGill.) McGill.	*Grevillea dissectifolia* (McGill.) Olde	P3	Nomenclatural synonym. See Olde (2022a).
Grevillea manglesii Pépin subsp. *manglesii*	*Grevillea manglesii* Pépin		Nomenclatural synonym. No subspecies recognised. See Olde (2022a).
Grevillea manglesii subsp. *ornithopoda* (Meisn.) McGill.	*Grevillea ornithopoda* Meisn.	P2	Nomenclatural synonym. See Olde (2022a).
Grevillea preissii subsp. *glabrilimba* Olde & Marriott	*Grevillea glabrilimba* (Olde & Marriott) Olde		Nomenclatural synonym. See Olde & Keighery (2022).
Grevillea preissii Meisn. subsp. *preissii*	*Grevillea preissii* Meisn.		Nomenclatural synonym. No subspecies recognised. See Olde & Keighery (2022).
Grevillea variifolia subsp. *bundera* Keighery	*Grevillea bundera* (Keighery) Olde & Keighery		Nomenclatural synonym. See Olde & Keighery (2022).
Grevillea variifolia C.A.Gardner & A.S.George subsp. *variifolia*	*Grevillea variifolia* C.A.Gardner & A.S.George		Nomenclatural synonym. No subspecies recognised. See Olde & Keighery (2022).
Grevillea sp. Cooljarloo (B.J. Keighery 28 B)	*Grevillea cooljarloo* Keighery & Olde	P1	Taxon formally published. See Olde & Keighery (2022).
Grevillea sp. Gillingarra (R.J. Cranfield 4087)	*Grevillea gillingarra* Olde & Keighery	T	Taxon formally published. See Olde & Keighery (2022).
Grevillea sp. Trayning (W. Johnston WJ 071)	*Grevillea tesselata* Olde	P1	Taxon formally published. See Olde (2022b).
Grona heterocarpa (L.) H.Ohashi & K.Ohashi	*Grona heterocarpos* (L.) H.Ohashi & K.Ohashi		Orthographic variant. See Ho *et al.* (2021).

Old Name	**New Name**	**Status**	**Comments**
Grona heterocarpa var. *strigosa* (Meeuwen) H.Ohashi & K.Ohashi	*Grona heterocarpos* var. *strigosa* (Meeuwen) H.Ohashi & K.Ohashi		Orthographic variant. See Ho *et al.* (2021).
Hakea lorea (R.Br.) R.Br.	*Hakea loreus* (R.Br.) R.Br.		Orthographic variant. See George & Sharr (2021).
Hakea lorea subsp. *borealis* W.R.Barker	*Hakea loreus* subsp. *borealis* W.R.Barker		Orthographic variant. See George & Sharr (2021).
Hakea lorea (R.Br.) R.Br. subsp. *lorea*	*Hakea loreus* (R.Br.) R.Br. subsp. *loreus*		Orthographic variant. See George & Sharr (2021).
Heliotropium aenigmatum Craven	*Euploca aenigmata* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium alcyonium Craven	*Euploca alcyonium* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium apertum Craven	*Euploca apertum* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium argyreum Craven	*Euploca argyrea* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium brachythrix Craven	*Euploca brachythrix* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium calvariavis Craven	*Euploca calvariavis* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium chrysocarpum Craven	*Euploca chrysocarpa* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium conocarpum Benth.	*Euploca conocarpa* (Benth.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium cunninghamii Benth.	*Euploca cunninghamii* (Benth.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium cupressinum Craven	*Euploca cupressina* (Craven) Diane & Hilger	P1	Nomenclatural synonym. See Hilger & Diane (2003).
Heliotropium dichotomum Craven	*Euploca dichotoma* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium discors Craven	*Euploca discordis* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium diversifolium Benth.	*Euploca diversifolia* (Benth.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium epacrideum Benth.	*Euploca epacridea* (Benth.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium euodes Craven	*Euploca euodes* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium flintii A.S.Mitch.	*Euploca flintii* (A.S.Mitch.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium foliatum R.Br.	*Euploca foliata* (R.Br.) Feuillet		Nomenclatural synonym. See Feuillet (2016).
Heliotropium foveolatum Craven	*Euploca foveolata* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium galioides Craven	*Euploca galioides* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium geocharis Domin	*Euploca geocharis* (Domin) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).

Old Name	New Name	Status	Comments
Heliotropium glabellum R.Br.	*Euploca glabella* (R.Br.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium glanduliferum Craven	*Euploca glandulifera* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium haesum Craven	*Euploca haesum* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium heteranthum (F.Muell.) Ewart & O.B.Davies	*Euploca heterantha* (F.Muell.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium inexplicitum Craven	*Euploca inexplicita* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium leptaleum Craven	*Euploca leptalea* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium microsalsoloides Craven	*Euploca microsalsoloides* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium mitchellii Craven	*Euploca mitchellii* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium moorei Craven	*Euploca moorei* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium muticum Domin	*Euploca mutica* (Domin) M.W.Frohl. & M.W.Chase	P3	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium nesopelydum Craven	*Euploca nesopelyda* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium nexosum Craven	*Euploca nexosa* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium ovalifolium Forssk.	*Euploca ovalifolia* (Forssk.) Diane & Hilger		Nomenclatural synonym. See Hilger & Diane (2003).
Heliotropium pachyphyllum Craven	*Euploca pachyphylla* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium paniculatum R.Br.	*Euploca paniculata* (R.Br.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium parviantrum Craven	*Euploca parviantrum* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium peckhamii Craven	*Euploca peckhamii* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium protensum Craven	*Euploca protensa* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium ramulipatens Craven	*Euploca ramulipatens* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium skeleton Craven	*Euploca skeleton* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium sphaericum Craven	*Euploca sphaerica* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium synaimon Craven	*Euploca synaimon* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium tachyglossoides Craven	*Euploca tachyglossoides* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).

Old Name	**New Name**	**Status**	**Comments**
Heliotropium tanythrix Craven	*Euploca tanythrix* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium tenuifolium R.Br.	*Euploca tenuifolia* (R.Br.) Diane & Hilger		Nomenclatural synonym. See Hilger & Diane (2003).
Heliotropium transforme Craven	*Euploca transformis* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium uniflorum Craven	*Euploca uniflora* (Craven) M.W.Frohl. & M.W.Chase	P1	Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium ventricosum R.Br.	*Euploca ventricosa* (R.Br.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium vestitum Benth.	*Euploca vestita* (Benth.) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Heliotropium viator Craven	*Euploca viator* (Craven) M.W.Frohl. & M.W.Chase		Nomenclatural synonym. See Frohlich *et al.* (2020).
Hypocalymma puniceum subsp. Cadoux (H. Demarz 10533)	*Hypocalymma polyandrum* Rye, Keighery & M.D.Barrett	P1	Taxon formally published. See Rye *et al.* (2022).
Hypocalymma sp. Cascade (R. Bruhn 20/896 CAS)	*Hypocalymma magnificum* Rye, Keighery & M.D.Barrett	T	Taxon formally published. See Rye *et al.* (2022).
Hypocalymma sp. Lake King (R.W. Purdie 3936)	*Hypocalymma inopinatum* Rye, Keighery & M.D.Barrett	P2	Taxon formally published. See Rye *et al.* (2022).
Ipomoea macrantha Roem. & Schult.	*Ipomoea violacea* L.		Taxonomic synonym. See Wood *et al.* (2020).
Isotoma petraea F.Muell.	*Lithotoma petraea* (F.Muell.) E.B.Knox		Nomenclatural synonym. See Knox (2014).
Kunzea affinis S.Moore × *Kunzea preissiana* Schauer	*Kunzea preissiana* Schauer		Misapplied name *p.p.* See Toelken & Craig (2007).
Kunzea affinis S.Moore × *Kunzea preissiana* Schauer	*Kunzea strigosa* Toelken & G.F.Craig		Misapplied name *p.p.* See Toelken & Craig (2007).
Latrobea colophona Chappill & C.F.Wilkins	*Latrobea colophon* Chappill & C.F.Wilkins	T	Orthographic variant. See George & Sharr (2021).
Leersia hexandra Sw.	n/a		Name made current. Taxon reinstated as occurring in WA. M. Hislop pers. comm. (23/03/2022).
Leptospermum inelegans Joy Thomps.	*Leptospermum roei* Benth.		Taxonomic synonym. See Binks *et al.* (2022).
Leptospermum sp. Peak Charles/ Norseman (K.R. Newbey 5243)	*Leptospermum incanum* Turcz.		Name synonymised. See Binks *et al.* (2022).
Leucopogon sp. Bolgart (M. Hislop & F. Hort MH 2486)	*Styphelia roseola* Hislop		Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Bungulla (R.D. Royce 3435)	*Styphelia caudata* Hislop	P3	Taxon formally published. See Hislop (2021).
Leucopogon sp. Cockleshell Gully (J.M. Powell 1749)	*Styphelia carolineae* Hislop	P2	Taxon formally published. See Hislop (2021).
Leucopogon sp. Corrigin (K. Kershaw KK 2091)	*Styphelia scabrella* Hislop		Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Dongolocking (K. Kershaw KK 2333)	*Styphelia papillosa* Hislop	P3	Taxon formally published. See Hislop & Nguyen (2022).

Old Name	**New Name**	**Status**	**Comments**
Leucopogon sp. Gingilup (N. Gibson & M. Lyons 590)	*Styphelia intricata* Hislop	P2	Taxon formally published. See Hislop (2021).
Leucopogon sp. Great Southern (R.S. Cowan A-586)	*Styphelia annulata* Hislop		Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Gunapin (F. Hort 808)	*Styphelia bracteolosa* Hislop	P3	Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Ironcaps (N. Gibson & K. Brown 3070)	*Styphelia platyneura* Hislop	P2	Name synonymised *p.p.* See Hislop & Nguyen (2022).
Leucopogon sp. Ironcaps (N. Gibson & K. Brown 3070)	*Styphelia subglauca* Hislop	P3	Name synonymised *p.p.* See Hislop & Nguyen (2022).
Leucopogon sp. Karroun Hill (K.R. Thiele 4167)	*Styphelia echinulata* Hislop	P2	Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Lake King (A.J.G. Wilson 65)	*Styphelia incerta* Hislop	P3	Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Lake Tay (W.R. Archer 2104138)	*Styphelia exarata* Hislop	P1	Taxon formally published. See Hislop (2021).
Leucopogon sp. Manypeaks (A.S. George 6488)	*Styphelia exilis* Hislop	T	Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Margaret River (J. Scott 207)	*Styphelia globosa* Hislop		Taxon formally published. See Hislop (2021).
Leucopogon sp. Southern Granite (E.D. Middleton EDM 266)	*Styphelia graniticola* Hislop	P2	Taxon formally published. See Hislop (2021).
Leucopogon sp. Tathra (M. Hislop 2900)	*Styphelia pallens* Hislop	P2	Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Walpole (R.J. Cranfield 10940)	*Styphelia madida* Hislop		Taxon formally published. See Hislop (2021).
Leucopogon sp. Wandering (F. Hort 419)	*Styphelia recurva* Hislop		Taxon formally published. See Hislop & Nguyen (2022).
Leucopogon sp. Yandanooka (M. Hislop 2507)	*Styphelia hyalina* Hislop	P3	Taxon formally published. See Hislop & Nguyen (2022).
Liparis habenarina (F.Muell.) Benth.	*Empusa habenarina* (F.Muell.) M.A.Clem. & D.L.Jones	P2	Nomenclatural synonym. See Barrett *et al.* (2022).
Machaerina sp. Blackwood (R. Davis 7681)	*Machaerina ascendens* R.L.Barrett & K.L.Wilson	P2	Taxon formally published. See Barrett & Wilson (2022).
Matricaria recutita L.	*Matricaria chamomilla* L.	*	Taxonomic synonym. See CHAH (2016).
Microcorys macredieana F.Muell.	*Microcorys macredieanus* F.Muell.		Orthographic variant. See George & Sharr (2021).
Myriocephalus guerinae F.Muell.	*Myriocephalus gueriniae* F.Muell.		Orthographic variant. See George & Sharr (2021).
Neptunia gracilis Benth.	n/a		Excluded taxon. This taxon does not occur in WA. See Bean (2022).
Neptunia gracilis f. *glandulosa* Windler	*Neptunia dimorphantha* Domin		Taxonomic synonym. See Bean (2022).
Neptunia gracilis Benth. f. *gracilis*	n/a		Excluded taxon. This taxon does not occur in WA. See Bean (2022).

Old Name	**New Name**	**Status**	**Comments**
Netrostylis capillaris (F.Muell.) R.L.Barrett, J.J.Bruhl & K.L.Wilson	n/a		Excluded taxon. This taxon does not occur in WA. R.L. Barrett *in litt.* (19/01/2022).
Phyllanthus amarus Schumach.	*Moeroris amara* (Schumach.) R.W.Bouman	*	Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus aridus Benth.	*Lysiandra arida* (Benth.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus baccatus Benth.	*Kirganelia baccata* (Benth.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus baeckeoides J.T.Hunter & J.J.Bruhl	*Lysiandra baeckeoides* (J.T.Hunter & J.J.Bruhl) R.W.Bouman	P3	Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus calycinus Labill.	*Lysiandra calycina* (Labill.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus eremicus R.L.Barrett & I.Telford	*Lysiandra eremica* (R.L.Barrett & I.Telford) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus erwinii J.T.Hunter & J.J.Bruhl	*Dendrophyllanthus erwinii* (J.T.Hunter & J.J.Bruhl) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus exilis S.Moore	*Cathetus exilis* (S.Moore) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus fuernrohrii F.Muell.	*Lysiandra fuernrohrii* (F.Muell.) R.W.Bouman	P3	Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus hamelinii I.Telford & R.L.Barrett	*Lysiandra hamelinii* (I.Telford & R.L.Barrett) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus indigoferoides Benth.	*Lysiandra indigoferoides* (Benth.) R.W.Bouman	P1	Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus lacerosus Airy Shaw	*Dendrophyllanthus lacerosus* (Airy Shaw) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus maderaspatensis L.	*Nellica maderaspatensis* (L.) Raf.		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus minutiflorus Müll. Arg.	*Cathetus minutiflorus* (Müll.Arg.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus saxosus F.Muell.	*Lysiandra saxosa* (F.Muell.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus scaber Klotzsch	*Lysiandra scabra* (Klotzsch) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus sulcatus J.T.Hunter & J.J.Bruhl	*Emblica sulcatus* (J.T.Hunter & J.J.Bruhl) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus tenellus Roxb.	*Moeroris tenella* (Roxb.) R.W.Bouman	*	Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus urinaria L.	*Emblica urinaria* (L.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Phyllanthus virgatus G.Forst.	*Cathetus virgatus* (G.Forst.) R.W.Bouman		Nomenclatural synonym. See Bouman *et al.* (2022).
Prosopis glandulosa Torr.	*Neltuma glandulosa* (Torr.) Britton & Rose	*	Nomenclatural synonym. See Hughes *et al.* (2022).

Old Name	**New Name**	**Status**	**Comments**
Prosopis glandulosa Torr. × *Prosopis velutina* Wooton	*Neltuma glandulosa* (Torr.) Britton & Rose × *Neltuma velutina* (Wooton) Britton & Rose	*	Nomenclatural synonym. See Hughes *et al.* (2022).
Prosopis glandulosa Torr. var. *glandulosa*	*Neltuma glandulosa* (Torr.) Britton & Rose var. *glandulosa*	*	Nomenclatural synonym. See Hughes *et al.* (2022).
Prosopis pallida (Willd.) Kunth	*Neltuma pallida* (Willd.) C.E.Hughes & G.P.Lewis	*	Nomenclatural synonym. See Hughes *et al.* (2022).
Pterostylis polyphylla (D.L.Jones & C.J.French) D.L.Jones & C.J.French	*Pterostylis neopolyphylla* Idrees & J.M.H.Shaw	P2	Nomenclatural synonym. See Idrees & Shaw (2021).
Ptilotus daphne Lally	*Ptilotus daphneae* Lally	P1	Orthographic variant. See George & Sharr (2021).
Rhaponticum repens (L.) Hidalgo	*Leuzea repens* (L.) D.J.N.Hind	*	Nomenclatural synonym. See Hind (2019).
Sauropus arenosus J.T.Hunter & J.J.Bruhl	*Synostemon arenosus* (J.T.Hunter & J.J.Bruhl) I.Telford & J.J.Bruhl	P3	Nomenclatural synonym. See Bouman *et al.* (2022).
Schoenus sesquispiculus C.B.Clarke	*Schoenus sesquispicula* C.B.Clarke		Orthographic variant. A typographic error in Green (1985).
Sida sp. A Kimberley Flora (P.A. Fryxell & L.A. Craven 3900)	*Sida* sp. Murray Springs (R.W.Johnson+ MRS919)		Name synonymised. R.M. Barker *in litt.* (01/07/2022).
Sida sp. C Kimberley Flora (T.E.H. Aplin 4982)	*Sida* sp. Walhallow Station (C.Edgoose 28/Oct/94)		Name synonymised. R.M Barker *in litt.* (01/07/2022).
Solanum nitidibaccatum Bitter	*Solanum styleanum* Dunal	*	Taxonomic synonym. See CHAH (2021c).
Soliva sessilis Ruiz & Pav.	*Cotula sessilis* (Ruiz & Pav.) Stace	*	Nomenclatural synonym. See Rich *et al.* (2019).
Spyridium sp. Jerdacuttup (A. Williams 332)	*Spyridium longicor* Kellermann & C.Clowes		Taxon formally published. See Kellermann & Clowes (2022).
Stylidium daphne Lowrie & Kenneally	*Stylidium daphneae* Lowrie & Kenneally	P2	Orthographic variant. See George & Sharr (2021).
Styphelia sp. Albany (M. Hislop 2218)	*Styphelia inframediana* Hislop		Taxon formally published. See Hislop (2021).
Styphelia sp. Tarin Rock (W.E. Blackall 1315)	*Styphelia blackallii* Hislop	P2	Taxon formally published. See Hislop (2022).
Swainsona sp. Karara (C. Godden & J. Hruban 24-26)	*Swainsona picta* R.W.Davis & T.Hammer	P1	Taxon formally published. See Davis & Hammer (2022).
Tetrapora verrucosa Turcz.	*Austrobaeckea verrucosa* (Turcz.) Rye		Nomenclatural synonym. See Rye (2021).
Thelymitra sp. South coast (G. Byrne 5133)	*Thelymitra porphyrosticta* F.Muell.	P2	Name synonymised. A.P. Brown *in litt.* (08/04/2022).
Trachymene oleracea subsp. *sedimenta* Rye	*Trachymene oleracea* subsp. *sedimentum* Rye	P1	Orthographic variant. See George & Sharr (2021).
Typhonium liliifolium Schott	*Lazarum liliifolium* (Schott) M.D.Barrett, A.Hay & Hett.		Nomenclatural synonym. See Hay *et al.* (2022).
Typhonium nudibaccatum A.Hay	*Lazarum nudibaccatum* (A.Hay) M.D.Barrett, A.Hay & Hett.	P1	Nomenclatural synonym. See Hay *et al.* (2022).

Old Name	New Name	Status	Comments
Typhonium peltandroides A.Hay, M.D.Barrett & R.L.Barrett	*Lazarum peltandroides* (A.Hay, M.D.Barrett & R.L.Barrett) M.D.Barrett, A.Hay & Hett.	P1	Nomenclatural synonym. See Hay *et al.* (2022).
Utricularia dunstaniae F.E.Lloyd	n/a		Excluded taxon. This taxon does not occur in WA. See Jobson *et al.* (2018).
Utricularia sp. Kununurra (C. Glover 81)	*Utricularia baliboongarnang* Baleeiro & R.W.Jobson	P2	Name synonymised. See Baleeiro & Jobson (2022).
Yakirra australiensis (Domin) Lazarides & R.D.Webster	*Panicum australiense* Domin		Nomenclatural synonym. See Zuloaga *et al.* (2018).
Yakirra australiensis (Domin) Lazarides & R.D.Webster var. *australiensis*	*Panicum australiense* Domin var. *australiense*		Nomenclatural synonym. See Zuloaga *et al.* (2018).
Yakirra australiensis var. *intermedia* R.D.Webster	*Panicum australiense* var. *intermedium* (R.D.Webster) Zuloaga		Nomenclatural synonym. See Zuloaga *et al.* (2018).
Yakirra majuscula (Benth.) Lazarides & R.D.Webster	*Panicum majusculum* Benth.		Nomenclatural synonym. See Zuloaga *et al.* (2018).
Yakirra muelleri (Hughes) Lazarides & R.D.Webster	*Panicum muelleri* (Hughes) Lazarides		Nomenclatural synonym. See Zuloaga *et al.* (2018).
Yakirra pauciflora (R.Br.) Lazarides & R.D.Webster	*Panicum pauciflorum* R.Br.		Nomenclatural synonym. See Zuloaga *et al.* (2018).

Acknowledgements

Collections staff at PERTH and the Department of Biodiversity, Conservation and Attraction's 'Taxonomic Review Committee' are acknowledged for their contributions to the information presented herein. Thank you to Lisa Wright and Nicole Wreford from the Department's library for sourcing difficult to access articles.

References

Areces-Berazain, F. & Ackerman, J.D. (2020). A revision of *Thespesia* and allied genera in Tribe Gossypieae (Malvaceae-Malvoideae). *Brittonia* 72(1): 62–110.

Baker, M.A., Cloud-Hughes, M.A., Rebman, J.P. & Majure, L.C. (2019). Nomenclatural changes in *Cylindropuntia* (Cactaceae). *Madroño; Journal of the California Botanical Society* 66(3): 92–96.

Baleeiro, P.C. & Jobson, R.W. (2022). Redescription of *Utricularia singeriana* and a new species *Utricularia baliboongarnang* Baleeiro & R.W.Jobson for north-eastern Western Australia. *Telopea* 25: 63–73.

Barker, W.R., Barker, R.M., Jessop, J. & Vonow, H. (ed.) (2005). Census of South Australian Vascular Plants 5th Edition. *Journal of the Adelaide Botanic Gardens Supplement* 1: 1–396.

Barrett, R.L. & Barrett, M.D. (2022). *Dianella lignosa* (Asphodelaceae), a new species from the north-west Kimberley region of Western Australia. *Telopea* 25: 197–202.

Barrett, R.L., Barrett, M.D. & Clements, M.A. (2022). A revision of Orchidaceae from the Kimberley region of Western Australia with new species of tropical *Calochilus* and *Dipodium*. *Telopea* 25: 203–270.

Barrett, R.L. & Wilson, K.W. (2022). *Machaerina ascendens* (Cyperaceae), a rare new species from the far south-west of Western Australia, and a new combination for *Schoenus abbreviatus* Nees. *Telopea* 25: 173–179.

Bean, A.R. (2020). A reassessment of *Bidens* (Asteraceae) in Australia. *Australian Systematic Botany Society Newsletter* 184: 44–45.

Bean, A.R. (2022). A revision of *Neptunia* Lour. (Leguminosae: subfamily Caesalpinioideae, Mimosoid clade) in Australia and Malesia. *Austrobaileya* 12: 59–106.

Binks, R.M., Hislop, M. & Byrne, M. (2022). Synonymisation of taxa, correction of a misapplied name and an updated key for the Western Australian *Leptospermum erubescens* species group (Myrtaceae: Leptospermeae). *Nuytsia* 33: 325–329.

Bouman, R.W., Kessler, P.J.A., Telford, I.R.H., Bruhl, J.J., Strijk, J.S., Saunders, R.M.K., Esser, H-J., Falcón-Hidalgo, B. & van Welzen, P.C. (2022). A revised phylogenetic classification of tribe Phyllantheae (Phyllanthaceae). *Phytotaxa* 540(1): 1–100.

Brockman, G. & French, C.J. (2022). *Eriochilus glareosus* (Orchidaceae), a new species from south-west Western Australia. *Nuytsia* 33: 217–220.

CHAH (Council of Heads of Australasian Herbaria) (2006). *National Species List*. https://id.biodiversity.org.au/name/ apni/93658 [accessed 23 November 2022].

CHAH (Council of Heads of Australasian Herbaria) (2016). *National Species List*. https://id.biodiversity.org.au/instance/apni/7001164 [accessed 13 December 2021].

CHAH (Council of Heads of Australasian Herbaria) (2021a). *National Species List*. https://id.biodiversity.org.au/instance/apni/51430981 [accessed 08 February 2022].

CHAH (Council of Heads of Australasian Herbaria) (2021b). *National Species List*. https://id.biodiversity.org.au/instance/apni/51430998 [accessed 08 February 2022].

CHAH (Council of Heads of Australasian Herbaria) (2021c). *National Species List*. https://id.biodiversity.org.au/instance/apni/51447841 [accessed 17 May 2022].

Chase, M.W., Cauz-Santos, L.A., Dodsworth, S. & Christenhusz, M.J.M. (2022). Taxonomy of the Australian *Nicotiana benthamiana* complex (*Nicotiana* section *Suaveolentes*; Solanaceae): five species, four newly described, with distinct ranges and morphologies. *Australian Systematic Botany* 35(5): 345–363.

Collins, T.L., Schmidt-Lebuhn, A.N., Andrew, R.L., Telford, I.R.H. & Bruhl J.J. (2022). There's gold in them thar hills! Morphology and molecules delimit species in *Xerochrysum* (Asteraceae; Gnaphalieae) and reveal many new taxa. *Australian Systematic Botany* 35(2): 120–185.

Curtis, A.L., Grierson, P.F., Batley, J., Naaykens, J., Fowler, R.M., Severn-Ellis, A. & Thiele, K.R. (2022). Resolution of the *Eremophila tietkensii* (Scrophulariaceae) species complex based on congruence between morphological and molecular pattern analyses. *Australian Systematic Botany* 35(1): 1–18.

Davis, R.W. & Hammer, T.A. (2022). *Swainsona picta* (Fabaceae), a new species from the Yalgoo bioregion, Western Australia. *Swainsona* 36: 71–73.

Feuillet, C. (2016). Two new combinations in *Euploca* Nutt. (Heliotropiaceae, Boraginales) and a conspectus of the species of the Guiana Shield area. *PhytoKeys* 61: 101–124.

Forster, P.I. (2021). *Gymnema* R.Br. and *Leichhardtia* R.Br. (Apocynaceae), reinstated genera for taxa previously included in *Marsdenia* R.Br.: a conspectus for Australia, New Guinea and the Solomon Islands. *Austrobaileya* 11: 1–18.

Frohlich, M.W., Thulin, M. & Chase, M.W. (2020). Ninety-three new combinations in *Euploca* for species of *Heliotropium* section *Orthostachys* (Boraginaceae sensu APG). *Phytotaxa* 434(1): 13–21.

George, A.S. & Sharr, F.A. (2021). *Western Australian Plant Names and their Meanings*. 4th edn. (Four Gables Press, Kardinya, Western Australia.)

Green, J.W. (1985). *Census of the Vascular Plants of Western Australia*. 2nd edn. (Western Australian Herbarium, Perth, Western Australia.)

Hammer, T.A. & Thiele, K.R. (2022). *Hibbertia archeri* (Dilleniaceae), a new and rare species from Western Australia with transcontinental affinities. *Swainsona* 36: 67–70.

Hay, A., Barrett, M.D. & Hetterscheid, W.L.A. (2022). New combinations in resurrected *Lazarum* A.Hay (Araceae–Areae). *Aroideana* 45(3): 133–137.

Hilger, H.H. & Diane, N. (2003). A systematic analysis of Heliotropiaceae (Boraginales) based on trnL and ITS1 sequence data. *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 125(1): 19–51.

Hind, D.J.N. (2019). *Leuzea repens*, a new combination (Compositae: Cardueae: Centaureinae). *Kew Bulletin* 74(2): Article: 20: 2.

Hislop, M. (2021). New species of Western Australian *Styphelia* (Ericaceae: Epacridoideae: Styphelieae) from the *S. pendula* and *S. conostephioides* groups. *Nuytsia* 33: 199–238.

Hislop, M. (2022). *Conostephium wonganense*, *Dielsiodoxa altimontana* and *Styphelia blackallii* – three rare, new epacrids (Ericaceae: Epacridoideae) from Western Australia. *Nuytsia* 33: 205–216.

Hislop, M. & Nguyen, H.K. (2022). A taxonomic review of the *Styphelia tamminensis* subgroup (Ericaceae: Epacridoideae: Styphelieae). *Nuytsia* 33: 275–320.

Hislop, M. & Wilson, A.J.G. (2022). A taxonomic update of *Stenanthera* (Ericaceae: Epacridoideae: Styphelieae), including description of a third species from Western Australia, an updated description of *S. pungens* and an Australia-wide key to species. *Swainsona* 36: 129–133.

Ho, B.C., Yeo, R.S.W. & Chen, L.M.J. (2021). A review of *Desmodium s.l.* (Leguminosae, subfamily Papilionoideae) in Singapore and nomenclature updates in the Malay Peninsula. *The Gardens' Bulletin, Singapore* 73(1): 49–80.

Hughes, C.E., Ringelberg, J.J., Lewis, G.P. & Catalano, S.A. (2022). Disintegration of the genus *Prosopis* L. (Leguminosae, Caesalpinioideae, mimosoid clade). *PhytoKeys* 205: 147–189.

Idrees, M. & Shaw, J.M.H. (2021). A new name for *Pterostylis polyphylla* (Orchidaceae). *Novon* 29(1): 194.

Jobson, R.W., Baleeiro, P.C. & Barrett M.D. (2018). Six new species of *Utricularia* (Lentibulariaceae) from Northern Australia. *Telopea* 21: 57–77.

Keighery, G.J. & Mitchell, A.A. (2022). The correct name for the weedy *Homalanthus* (Euphorbiaceae) in Western Australia. *Nuytsia* 33: 35–37.

Kellermann, J. & Clowes, C. (2022). *Spyridium longicor*, a new species from Western Australia (Rhamnaceae: Pomaderreae). *Swainsona* 36: 97–100.

Knapp, S. (2022). A revision of *Lycianthes* (Solanaceae) in Australia, New Guinea, and the Pacific. *PhytoKeys* 209: 1–134.

Knox, E.B. (2014). The dynamic history of plastid genomes in the Campanulaceae *sensu lato* is unique among angiosperms. *Proceedings of the National Academy of the United States of America* 111(30): 11097–11102.

Lepschi, B.J. (2022). *Exocarpos capnodioides* (Santalaceae), a new species from southern Australia allied to *E. aphyllus*. *Nuytsia* 33: 103–111.

Lysak, M.A., Edginton, M., Zuo, S., Guo, X., Mandáková, T. & Al-Shehbaz, I.A. (2022). Transfer of two *Arabidella* and two *Cuphonotus* species to the genus *Lemphoria* (Brassicaceae) and a description of the new species *L. queenslandica*. *Phytotaxa* 549(2): 235–240.

Naive, M.A.K., Hein, K.Z., Kumar, P. & Ormerod, P. (2022). *Eulophia myanmarica* (Orchidaceae), a new species from Myanmar and notes on *Geodorum densiflorum*. *Phytotaxa* 548(2): 288-294.

Nazarova, O. & Hislop, M. (2021). *Convolvulus pyrophilus* (Convolvulaceae), a new post-fire ephemeral, and an updated illustrated key to the Western Australian species. *Nuytsia* 32: 159–165.

Nge, F.J. & Thiele, K.R. (2022). *Calytrix calingiri*, a new species from the *Calytrix acutifolia* species group (Myrtaceae: Chamelaucieae). *Nuytsia* 33: 251–261.

Nicolle, D. (2021). *Classification of the eucalypts (Angophora, Corymbia and Eucalyptus)* Version 5. http://www.dn.com.au/Classification-Of-The-Eucalypts.pdf [accessed 07 September 2022].

Nicolle, D. & French, M.E. (2021). A taxonomic revision of the semi-cryptic narrow-leaved mallees (*Eucalyptus* series *Porantherae*, Myrtaceae) from southern Australia. *Swainsona* 35: 73–152.

Olde, P.M. (2022a). *Grevillea manglesii* (Proteaceae: Grevilleoideae: Hakeinae) revisited. *Telopea* 25: 33–62.

Olde, P.M. (2022b). *Grevillea tesselata* Olde (Proteaceae: Grevilleoideae: Hakeinae), a rare new species of uncertain affinity from the Avon Wheatbelt region of south-west Western Australia. *Telopea* 25: 309–318.

Olde, P.M. & Keighery, G.J. (2022). New species and taxonomic changes in the *Grevillea thelemanniana* Group (Proteaceae: Grevilleoideae: Hakeinae) from south-west Western Australia. *Telopea* 25: 331–352.

Parmar, G., Dang, V-C., Rabarijaona, R.N., Chen, Z-D., Jackes, B.R., Barrett, R.L., Zhang, Z-Z., Niu, Y-T., Trias-Blasi, A., Wen, J. & Lu, L-M. (2021). Phylogeny, character evolution and taxonomic revision of *Causonis*, a segregate genus from *Cayratia* (Vitaceae). *Taxon* 70(6): 1188–1218.

Rich, T.C.G., McVeigh, A. & Stace, C.A. (2019). New taxa and new combinations in the British Flora. *Edinburgh Journal of Botany* 76(2): 173–180.

Robins, T.P., Binks, R.M., Byrne, M. & Hopper, S.D. (2021). Contrasting patterns of population divergence on young and old landscapes in *Banksia seminuda* (Proteaceae), with evidence for recognition of subspecies. *Biological Journal of the Linnean Society* 133(2): 449–463.

Rye, B.L. (2021). *Austrobaeckea*, a new south-western Australian genus of Myrtaceae (Chamelaucieae: Hysterobaeckeinae). *Nuytsia* 32: 173–197.

Rye, B.L. (2022). An expanded circumscription and revision of the Western Australian genus *Balaustion* (Myrtaceae: Chamelaucieae: Hysterobaeckeinae). *Nuytsia* 33: 149–204.

Rye, B.L., Keighery, G.J. & Barrett, M.D. (2022). Description of a new south-western Australian plant group, *Hypocalymma* sect. *Grandiflora* (Myrtaceae: Chamelaucieae: Astarteinae). *Nuytsia* 33: 233–249.

Rye, B.L. & Wilson, Peter G. (2022). Reduction of *Corynanthera* to the synonymy of *Micromyrtus* (Myrtaceae: Chamelaucieae: Micromyrtinae). *Nuytsia* 33: 321–324.

Shelton, L.R.J. & Thiele, K.R. (2022). *Drummondita billyacatting* (Rutaceae), a new, range-restricted species from Western Australia. *Nuytsia* 33: 19–27.

Sinou, C., Cardinal-McTeague, W. & Bruneau A. (2020). Testing generic limits in Cercidoideae (Leguminosae): Insights from plastid and duplicated nuclear gene sequences. *Taxon* 69(1): 67–86.

State of Western Australia (2022). Biodiversity Conservation (Listing of Native Species) (Flora) Order 2022. *Western Australian Government Gazette* 2022(144): 4763–4768. https://www.legislation.wa.gov.au/legislation/statutes.nsf/ gazettes2022.html [accessed 24 January 2023].

Thiele, K.R. & Hammer, T.A. (2022). *Hibbertia subvillosa* (Dilleniaceae), a new Western Australian species segregated from *H. striata*. *Australian Journal of Taxonomy* 8: 1–5.

Thiele, K.R., Keighery, G.J., Nge, F.J. & Rye, B.L. (2022). Three new Western Australian species related to *Calytrix violacea* (Myrtaceae: Chamelaucieae). *Nuytsia* 33: 221–232.

Toelken, H.R. (1996). A revision of the genus *Kunzea* (Myrtaceae) I. The Western Australian section *Zeanuk*. *Journal of the Adelaide Botanic Gardens* 17: 29–106.

Toelken, H.R. & Craig, G.F. (2007). *Kunzea acicularis*, *K. strigosa* and *K. similis* subsp. *mediterranea* (Myrtaceae) – new taxa from near Ravensthorpe, Western Australia. *Nuytsia* 17: 385–396.

Wege, J.A. (2022). *Stylidium milleri* (Stylidiaceae), a striking discovery from south-western Australia. *Nuytsia* 33: 15–18.

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora. Department of Biodiversity, Conservation and Attractions*. https://florabase.dpaw.wa.gov.au/ [accessed 24 January 2023].

Williams, A.R. (2022). *Austrostipa* (Poaceae) in Western Australia: new species, new records, keys, and character notes. *Nuytsia* 33: 39–101.

Wood, J.R.I., Muñoz-Rodríguez, P., Williams, B.R.M. & Scotland, R.W. (2020). A foundation monograph of *Ipomoea* (Convolvulaceae) in the New World. *PhytoKeys* 143: 1–823.

Zuloaga, F.O., Salariato, D.L. & Scataglini, A. (2018). Molecular phylogeny of *Panicum s. str.* (Poaceae, Panicoideae, Paniceae) and insights into its biogeography and evolution. *PLoS ONE* 13(2): 1–39. https://doi.org/10.1371/journal.pone.0191529

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01044

Nuytsia 34: 21–60
Published online 21 March 2023

Update to the taxonomy of *Hypocalymma* sect. *Hypocalymma* (Myrtaceae: Chamelaucieae), including hybrids and new species

Greg J. Keighery, Barbara L. Rye[1] and Catherine Tauss

Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[1] Corresponding author, email: Barbara.Rye@dbca.wa.gov.au

Abstract

Keighery, G.J., Rye, B.L. & Tauss, C. Update to the taxonomy of *Hypocalymma* sect. *Hypocalymma* (Myrtaceae: Chamelaucieae), including hybrids and new species. *Nuytsia* 34: 21–60 (2023). In updating the taxonomy of *Hypocalymma* (Endl.) Endl. sect. *Hypocalymma* (Myrtaceae: Chamelaucieae), the section is described, a key is provided to the species and hybrids, full descriptions given for 11 species (three of them new, one reinstated) and three hybrids (one newly named). Taxa needing further study are noted. Five species and two of the hybrids described here have conservation priority. Two new species are described from the *H. xanthopetalum* F.Muell. complex as *H. lateriticola* Keighery & Rye and *H. quadrangulare* Rye & Keighery. The circumscription of *H. angustifolium* (Endl.) Schauer is reduced with the reinstatement of *H. suave* Lindl. and the description of the new species *H. balbakiae* Tauss & Rye. A northern variant of *H. balbakiae* (previously known as *H. angustifolium* subsp. Hutt River) is considered to be insufficiently distinct to recognise formally as a subspecies. Evidence is presented that one previously named and two phrase-named taxa are hybrids. Two of the hybrids are known from more than one location and have been recorded in hybrid swarms: one between *H. angustifolium* and *H. tetrapterum* Turcz. is named as *H.* × *proliferum* Keighery & Rye, while the other, *H.* × *linifolium* Turcz., has the parent species *H. angustifolium* and *H. lateriticola*. The third hybrid is *H. tenuatum* × *H. xanthopetalum*. The description of *H. jessicae* Strid & Keighery is broadened to include a new variant that has mostly higher ovule and stamen numbers. Amendments are made to the stamen and ovule numbers recorded for *H. sylvestre* Strid & Keighery; this species has up to 200 stamens, which is the highest stamen number known for the tribe Chamelaucieae DC. A new fruit type that is indehiscent and somewhat winged, is recorded for the genus; it occurs only in *H. serrulatum* Strid & Keighery, which also has an unusual breeding system.

Introduction

This paper updates the taxonomy of *Hypocalymma* (Endl.) Endl. sect. *Hypocalymma* and presents a key to its species and three of its hybrids. Fairly extensive natural hybridisation within this section has contributed to difficulties in determining how many species should be recognised. Recent collections at several sites where there are hybrid swarms, and observations at sites where co-occurring species fail to hybridise, have now resolved some of the taxonomic problems. The main hybrids are described along with descriptions of their parent species. One old name is reinstated and three new species are named. Some previously named taxa are also described because they have changed in delimitation or

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

because significant new data are now available to correct or enlarge their previous descriptions, for example the presence of a new kind of fruit in the genus, found only in *H. serrulatum* Strid & Keighery.

Background

Hypocalymma is widely distributed in, and restricted to, the South West Botanical Province of Western Australia (Rye 2013: Figure 5C). It comprises more than thirty species.

Recent publications on *Hypocalymma* began with a review of the whole genus (Strid & Keighery 2002) in which eleven new taxa were named. Two of these new taxa were originally treated as subspecies but both have subsequently been raised to the species level (Rye 2010; Rye *et al.* 2013).

Four sections are now recognised in *Hypocalymma*. Two sections that are distinguished from *Hypocalymma* (Endl.) Endl. sect. *Hypocalymma* by their smooth to colliculate seeds, sect. *Cardiomyrtus* Schauer with five species and sect. *Verticilla* Rye with two species, were described in Rye *et al.* (2013). Another small section of five species, distinguished by having petals much longer than the stamens, has been described as sect. *Grandiflora* Rye, Keighery & M.D.Barrett (Rye *et al.* 2022). The remaining species belong to sect. *Hypocalymma*, which is by far the largest section; a total of 13 manuscript and phrase names (Table 1) have been applied to its members.

Need for further work in *Hypocalymma* sect. *Hypocalymma*

Two species complexes in need of further study are the *H. angustifolium* R.Br. complex and the *H. xanthopetalum* F.Muell. complex. The current study addresses some, but not all, of the problems in both complexes. Additional species or subspecies possibly should be recognised formally. Two varieties named by Schauer (1844), *H. angustifolium* var. *acerosum* Schauer and var. *verrucosum* Schauer, belong to the *H. angustifolium* complex but we have not examined all the relevant syntypes and so are not in a position to be able to select lectotypes. Each variety contains syntypes that might belong to different taxa.

Methods

Our treatment of hybrid taxa follows the guidelines in Thiele and Parker (2014) in determining whether they qualify for conservation status. For the single hybrid that does not qualify, localities have been obfuscated because one of the parent species does have conservation status. We have opted to use hybrid formulae for taxa known only from one or two specimens but to use epithets for more commonly encountered hybrids that are found in swarms because those have the potential to become permanently established in an intermediate ecotype between those of the parents or to maintain populations where the parent species are no longer present. This is the opposite approach to that taken by Hopper and Brown (2001: 20), who opted to use formulae for hybrids found in swarms and give formal names to those that are only found as sporadic individuals amongst mixed populations of their presumed parents. Either way, the occurrence of backcrosses in hybrid swarms makes it difficult to describe just the characteristics of the hybrids, i.e. excluding back-crosses, as we have attempted to do here.

Type specimens housed at PERTH or borrowed from MEL and K were examined. For the remainder of types cited, their images were viewed on *Global Plants* (https://plants.jstor.org/). Sharr (2021) was consulted for the derivations of epithets.

Table 1. Informal names for taxa belonging to *Hypocalymma* sect. *Hypocalymma*, showing date established and current name.

Date established	Manuscript or phrase name	Published name
1948	*Hypocalymma xanthopetalum* var. *linearifolium* C.A.Gardner ms	*Hypocalymma gardneri* Strid & Keighery
1991	*Hypocalymma* sp. Badgingarra (G.J. Keighery 4595)	*Hypocalymma serrulatum* Strid & Keighery
1992	*Hypocalymma xanthopetalum* var. Three Springs-Eneabba (W.E. Blackall 4393)	*Hypocalymma hirsutum* Strid & Keighery
1993	*Hypocalymma* sp. Cataby (G.J. Keighery 5151)	*Hypocalymma* × *proliferum* Keighery & Rye
1993	*Hypocalymma* sp. Lesueur (E.A. Griffin 1972)	*Hypocalymma tenuatum* Strid & Keighery
1998	*Hypocalymma* sp. Chittering (T. Palmer 1)	*Hypocalymma sylvestre* Strid & Keighery
1998	*Hypocalymma xanthopetalum* var. Dandaragan (C.A. Gardner 9014)	*Hypocalymma lateriticola* Rye & Keighery
2007	*Hypocalymma* sp. Dandaragan (C.A. Gardner 9014)	*Hypocalymma lateriticola* Rye & Keighery
2007	*Hypocalymma* sp. Gairdner Range (C.A. Gardner 9091)	*Hypocalymma tenuatum* × *H. xanthopetalum*
2007	*Hypocalymma* sp. Nambung (R. Spjut & R. Smith s.n. 22/09/1992)	*Hypocalymma quadrangulare* Keighery & Rye
2009	*Hypocalymma angustifolium* subsp. Dandaragan plateau (S. Patrick 702 A)	*Hypocalymma angustifolium* (Endl.) Schauer
2009	*Hypocalymma angustifolium* subsp. Hutt River (S. Patrick 2982)	*Hypocalymma balbakiae* Tauss & Rye
2009	*Hypocalymma angustifolium* subsp. Swan Coastal Plain (G.J. Keighery 16777)	*Hypocalymma balbakiae* Tauss & Rye

Descriptions are based on well pressed herbarium material, with measurements taken only from the larger leaves of each specimen and from fully mature organs as far as possible. Style measurements include the basal inset portion (when present) and are taken from fully mature flowers or from fruits. The fruit height and width are given before the valves begin to open; the fruit's height is reduced but its width expanded as the valves open sufficiently to release the seeds. Only fully mature seeds were measured, avoiding any similar-looking chaff. Seeds freshly extracted from the fruit were used where possible to avoid the possibility of the white elaiosome (inner protrusion) having been damaged. Sometimes there are chaff pieces that resemble seeds in both size and shape, but they are empty; they tend to be paler than the seeds and differ in the texture of the inner protrusion.

Description of *Hypocalymma* sect. *Hypocalymma*

Mostly small *shrubs* up to 1.5 m high, rarely up to 3 m high; flowering stems with flowers borne at few to numerous consecutive nodes, each node usually with 4 flowers forming a cluster. *Leaves* opposite and decussate, usually concolorous. *Peduncles* very reduced or up to 2.5 mm long, mostly 2-flowered. *Pedicels* absent or short. *Flowers* each subtended by a pair of opposite bracteoles, with each pair of flowers often subtended by a similar or somewhat shorter bract. *Hypanthium* shallowly cup-shaped, with a broad lobe corresponding with each loculus of the ovary. *Sepals* tending to be about half as long as the petals, often scarious, persistent in fruit. *Petals* 1.5–5.5 mm long, white to bright yellow or to deep pink, persistent in fruit in most species. *Staminodes* usually absent. *Stamens* 12–200 in up to 3 series, united into a continuous ring at base or connate for some distance, rarely (when few) all antisepalous, about as long as or longer than the petals. *Anther cells* often curved around a central ventral connective gland, longitudinally dehiscent. *Ovary* 2- or 3-locular, usually prominently ridged on the summit; ovules 1–11 per loculus. *Fruits c.* 1/2–3/4-superior, broader than long to slightly longer than broad, 1.3–4.5 mm long, thick-walled, dehiscent by terminal valves or (in *H. serrulatum*) indehiscent. *Seeds* 1.3–2.65 mm long, with a large cavity and a prominent protrusion on the inner surface; testa of seed body crustaceous, reticulate-pitted, brown; inner protrusion (elaiosome) concentrated at the distal end of the cavity, nearly always also extending along each lateral margin of the cavity and often extending slightly beyond the apex of seed body, white or whitish, fleshy.

Size and distribution. A section with 21 species now recognised, extending from Kalbarri National Park south to Augusta and south-east to Cape Arid National Park, Western Australia.

Habit. Section *Hypocalymma* includes single-stemmed reseeder species and lignotuberous resprouter species. One of the lignotuberous species from the *H. angustifolium* complex was studied in swamp communities near Gnangara on the Swan Coastal Plain by Dodd *et al.* (1984) and was found to be unusual in this habitat in having both its taproot and lateral roots well developed; the only other species with this characteristic was a member of the related genus *Astartea* DC.

Pollinators. *Hypocalymma* species attract numerous insect species to their readily accessible nectar, including records by Houston (2000) of native bee species of *Hylaeus* and *Leioproctus* visiting flowers of the *H. angustifolium* complex. An image showing a bee fly (*Meomyia*) feeding from the *H. angustifolium* complex is given in Hansen and Horsfall (2016) and a wasp is shown here in Figure 1A. Other insects recorded visiting members of this plant complex include Jewel and Melyrid beetles, Thynnine wasps and a Zygaenid moth (Brown *et al.* 1997; Lamont 1985).

There is also a record of the Brown Honeyeater visiting the flowers of *H. xanthopetalum* and the Honey Possum visiting both *H. strictum* Schauer and *H. xanthopetalum* flowers (Brown *et al.* 1997).

Colour changes often act as a signal to pollinators that old flowers have passed the stage of nectar production. At a Crystal Brook locality where a member of the *H. angustifolium* complex (probably *H. angustifolium s. str.*) was associated with granite outcrops, Lamont (1985: 147) recorded an average of over 35,000 flowers per plant, of which over 5,000 were being visited by pollinators. Peak nectar production and pollinator visitation at Crystal Brook were restricted to the phase where the flowers were white. Within three days the flowers had turned to deep pink and were no longer producing any nectar. Four species, one bee, one wasp and two beetles, were observed taking nectar but none of these was harvesting pollen.

Detrimental insect associations. As discussed in previous papers (e.g. Rye 2013) on the *Astartea-Hypocalymma-Cyathostemon* clade, *Callococcus* (Hemiptera family Eriococcidae) is a sap-feeding genus that uses all three plant genera as hosts but does not attack any other members of the tribe Chamelaucieae DC. The characteristic shape of female *Callococcus* scales is illustrated in Rye *et al.* (2013: Figure 2C). Another kind of stem-attached scale, which has been recorded on a specimen of a member of the *H. angustifolium* complex (*S.A. Fisher* 338), is produced by a bug species in the Diaspididae.

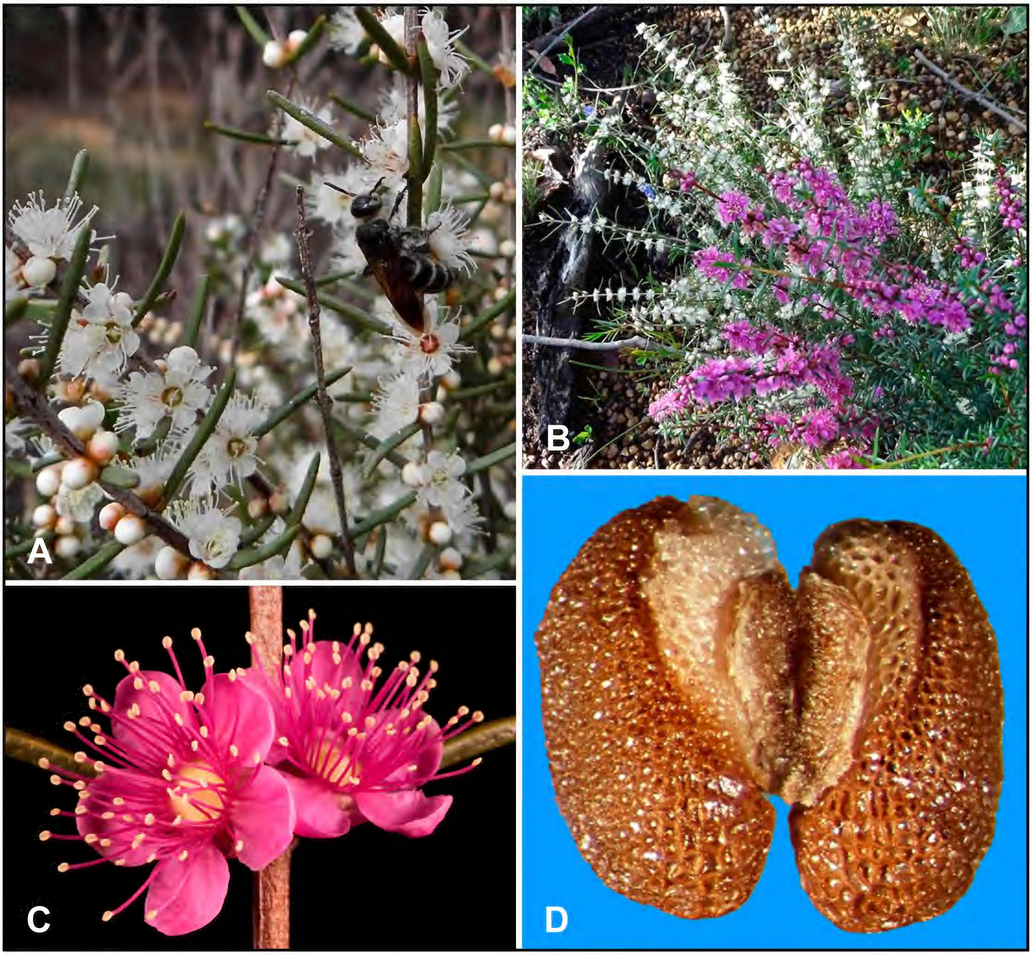

Figure 1. A – potential wasp pollinator on *Hypocalymma angustifolium*, showing the plant's relatively few stamens and flattened, tapering leaves and the ovary summit green at anthesis and reddish in late flower; B – co-occurrence at Korijekup Nature Reserve of the pink-flowered *H. robustum* and a white-flowered member of the *H. angustifolium* complex; C – *H. robustum* flowers with a yellow ovary summit and terminal style; D – *H. balbakiae*, two placentas with an apparently fertile (but actually empty) seed attached to the placenta on the left, showing its whitish eliaosome, and a more obviously infertile seed attached to the other placenta. The reticulate-pitted testa is clearly visible. Images by Greg Keighery taken on 9 August 2013 (A) and 12 September 2017 (B), by Kevin Thiele from *K.R. Thiele* 3043 (C) and by Alex Williams from *B.L. Rye*, *F. Hort & J. Hort* BLR 241206 (D).

Many other kinds of scales of sap-feeding insects are found on the leaves of members of *H.* sect. *Hypocalymma*, such as black scales formed by the larvae of white flies (Hemiptera family Aleyrodidae), but less commonly than in *H.* sect. *Cardiomyrtus* (see Rye *et al.* 2013 for details of scale-forming insects in that section).

In the *H. angustifolium* complex, Slater (1975, 1976) documented the destruction of seeds by diverse Lygaeid bugs. The 12 species of bug listed belonged to 11 genera and five of these species were also listed for *H. robustum* (Endl.) Lindl.

Breeding systems. *Hypocalymma* species are protandrous, typically releasing their pollen well before the stigma matures. Previously unpublished pollination trials were conducted by one of us (GJK) on glasshouse-grown specimens of seven species of *Hypocalymma*, including five members of sect. *Hypocalymma*. In six of the species, *H. angustifolium*, *H. cordifolium* Schauer, *H. ericifolium* Benth., *H. robustum*, *H. speciosum* Turcz. and *H. xanthopetalum*, pollen is normally well dispersed before stigma maturation. Little fruit and seed set occurred after controlled self-pollination in these species, whereas over 80% of fruits set seed after cross-pollination, suggesting all are strongly outbreeding.

Unlike those taxa, the seventh species, *H. serrulatum*, has anthers loosely clustered around the style and dehiscing only shortly before the stigma matures such that some of their pollen is deposited directly onto the mature stigma. Flowers pollinated naturally by this means, and also artificially selfed flowers, had a similar level of successful fruit set (79%) to flowers that were cross-pollinated (82%). There seems to be little nectar produced in *H. serrulatum* compared to other *Hypocalymma* species, suggesting that this species may be modally inbreeding, although cross-pollination is not excluded. Honeybees were observed visiting wild stands of *H. serrulatum* so the species does attract some potential insect pollinators.

Seed dispersal. In *Hypocalymma* the capsules normally remain attached to the plants until after they have dehisced by regular valves across the summit to release the seeds. However, *H. serrulatum* fruits are shed intact from the plant, i.e. they are multi-locular, indehiscent diaspores. The diaspores are somewhat three-winged on the summit and are usually only 1-seeded. How effective these wings are in enhancing dispersal of the diaspores needs investigation in the field. The development of indehiscent fruits within genera that are characterised by capsules has been documented in several other genera of tribe Chamelaucieae, including the closely related genus *Astartea* (Rye 2013).

Myrmechocory plays an important role in seed dispersal in *Hypocalymma*, as discussed in Rye *et al.* (2013). The elaiosome consists of a large white protrusion on the inner surface of the seeds, as can be seen on the seeds of *H. elongatum* (Strid & Keighery) Rye illustrated in Rye *et al.* (2013: Figure 4A). Ants have been observed by one of us (GJK) dispersing the seeds of *H. ericifolium* at Harvey.

Co-occurring species. Where species of *Hypocalymma* co-occur there are generally differences in habitat and in some cases there are also differences in flowering time and probably chromosome number. Despite this, hybridisation is common in the section.

Two of the natural hybrids recorded previously have a parent species from the *H. xanthopetalum* complex, which is fairly widespread in the northern part of the range of *Hypocalymma*, and most of them have a parent in the *H. angustifolium* complex. The latter complex has a large distribution covering about half of the South West Botanical Province, overlapping the ranges of many other members of the genus. One example of co-occurrence (Figure 1B) is between a member of this complex and the pink-flowered *H. robustum* (Figure 1C).

Notes. Members of the *H. angustifolium* complex were used by indigenous people to treat skin conditions, headaches and nasal congestion (Hansen & Horsfall 2016). Some species, notably *H. robustum* and members of the *H. angustifolium* complex, are important in horticulture and the cut flower trade.

Key to species and main hybrids of *Hypocalymma* sect. *Hypocalymma*

*Indicates a taxon that is keyed out more than once. Back-crossed hybrid specimens
may occasionally key out to a parent species.

1. Ovary 2-locular

2. Leaves 50–70 mm long. Petals white or cream. Ovules 8–11 per loculus (Murchison River area) .... **H. longifolium**

2: Leaves 8–32 mm long. Petals pale to deep pink. Ovules 1–4 per loculus

3. Ovules 1 per loculus

4. Shrub up to 1.6 m high; branchlets with widely spaced leaves. Largest leaves ± sessile, 20–32 mm long. Flowers borne at 3–13 consecutive nodes. (E edge of Stirling Range–Wellstead) .... **H. elongatum**

4: Shrub 0.3–1 m high; branchlets with densely clustered leaves. Largest leaves usually with a petiole 0.4–1.3 mm long and blade 6–15 mm long. Flowers borne at 1–3(–5) consecutive nodes (Ravensthorpe Ra.–Fitzgerald River NP) .... **H. jessicae***

3: Ovules 2–4 (usually 3) per loculus

5. Leaves 15–30 mm long, 1.2–3 mm wide, distinctly wider than thick. Petals medium to deep pink, 4–5.5 mm long (Moore River–Walpole) .... **H. robustum**

5: Leaves 3–16(–25) mm long, 0.6–1 mm wide, very thick. Petals pale to medium pink, 2.7–4 mm long

6. Leaves densely arranged on the branchlets; petiole usually well defined, and 0.4–1.3 mm long. Stamens (35–)55–100 (Ravensthorpe Ra.–Fitzgerald River NP) .... **H. jessicae***

6: Leaves widely spaced on the branchlets; petiole ± absent or poorly defined, up to 0.5 mm long. Stamens 25–55

7. Young stems with a rough surface of star-like protruding oil glands. Leaves 2.5–9(–13) mm long, with stellate protrusions similar to those on the stems (Mount Barker area–Cape Arid NP) .... **H. asperum**

7: Young stems smooth. Leaves 6–25 mm long, ± smooth (Augusta–Hassell Beach)..... **H. strictum**

1: Ovary 3-locular

8. Ovules 2–5 per loculus. Flowers yellow and with style base terminal on summit of ovary (see Figure 1C). Stamens 55–200. Stigma with long papillae (except in *H. sylvestre*), 0.15–0.5 mm diam. including the papillae.

9. Flowers 12–15 mm diam., densely arranged at 1–3 consecutive nodes. Ovules 3–5 in most loculi. Style 6–8 mm long; stigma with low papillae or smooth (Chittering area) .... **H. sylvestre**

9: Flowers 5–11 mm diam., at up to 8(–16) consecutive nodes and often fairly widely spaced. Ovules 2 per loculus. Style 3.5–5.5 mm long; stigma with elongated papillae (*H. xanthopetalum* complex)

10. Leaves hairy on both surfaces, sometimes becoming scabrid on adaxial surface. Flowers bright yellow, turning orange with age. Stamen filaments united for 1/3 to almost half their length (Eneabba–Mt Peron area) .... **H. hirsutum**

10: Leaves glabrous or rarely scabrid on the surfaces, often ciliate on the margins. Flowers pale or lemon yellow, then fading. Stamen filaments united for up to 1/4 of their length

11. Young stems 4-angled, glabrous

12. Young stems with ridges incurved and often flattened over surface of stem. Leaf margins scarious, denticulate. Anthers 0.3–0.35 mm long. Occurring near the coast in the Spearwood soil type (Nambung NP–Moore River State Forest) .... **H. quadrangulare**

12: Young stems with ridges projecting at right angles to the adjacent surface of stem. Leaf margins entire in most specimens. Anthers *c.* 0.5 mm long. Occurring further inland in lateritic soils (Badgingarra–Dandaragan area) .... **H. lateriticola**

11: Young stems ± terete or irregular, hairy

13. Lax, widely spreading subshrub to 0.3 m high, with numerous very fine stems from the base. Leaves 0.4–1.5 mm wide (Mt Lesueur area) .... **H. gardneri**

13: Low-growing shrub up to 0.8(–1.2) m high, with multiple stems from a lignotuber but with fewer stems that are not as fine as in *H. gardneri*. Leaves (2–)3–9 mm wide (Mingenew–Muchea) .... **H. xanthopetalum**

8: Ovules solitary in each loculus. Flowers white, pink or yellow, with style base slightly to deeply inset into ovary (rarely not inset in *H.* × *linifolium*). Stamens 12–55. Stigma with low papillae or entire (except sometimes in *H. tenuatum* × *H. xanthopetalum*), 0.05–0.1(–0.15) mm diam.

14. Style base usually only slightly inset, although sometimes seated between prominent wings, rarely terminal (see Figure 1C).

15. Leaves less than twice as wide as thick. Flowers opening predominantly in autumn and winter. Ovary 3-winged on summit. Fruits shed with seeds intact (Badgingarra area) .... **H. serrulatum**

15: Leaves more than twice as wide as thick. Flowers opening predominantly in spring. Ovary 3-ridged on summit. Fruits dehiscent while attached to the plant, releasing seeds through 3 terminal valves

16. Stems minutely hairy. Leaves 1.2–2 mm wide (Mt Lesueur NP) .... **H. tenuatum × H. xanthopetalum**

16: Stems glabrous. Leaves 2–4 mm wide (Badgingarra–Dandaragan area)................. **H. × linifolium**

14: Style base inset in a cylindrical depression

17. Flowering stems densely papillose and/or narrowly winged. Leaves often with oil glands star-like or surrounded by a circle of papillae

18. Leaves 0.5–1.3 mm wide; apical point 0.2–0.4 mm long, Petals 2–2.5 mm long (Lesueur NP–Warradarge)... **H. tenuatum**

18: Leaves 2–7 mm wide; apical point absent or up to 0.2 mm long. Petals 3–4 mm long (Eneabba–S of Badgingarra) .... **H. tetrapterum**

17: Flowering stems not papillose, not winged. Leaves with glands not as above

19. Young flowering stems with a loose papery epidermis obscuring their shape, bearing a dense inflorescence. Leaves 6–20 mm long. Petals cream to bright yellow

20. Petals 2.3–4 mm long, usually yellow. Stamens 20–50 in a full circle (N of Harvey–Augusta–Walpole)... **H. ericifolium**

20: Petals 1.5–2.3 mm long, usually cream. Stamens 12–20, often with gaps opposite the petals (Lake Jasper–Cape Riche) .... **H. scariosum**

19: Young flowering stems obviously 4-angled, usually with obvious gaps between the nodes of the inflorescence. Leaves (8–)15–50 mm long. Petals white or pink

21. Leaves with minutely crenulate margins; apical point 0.3–1.5 mm long, if less than 0.6 mm long then uncinate. Seeds 1.4–1.8 mm long

22. Shrubs lignotuberous. Leaves with apex straight but the apical point sometimes recurved; apical point 0.7–1.5 mm long. Associated with wetlands or watercourses, mainly near the coast, always well west of the range of *H. uncinatum* (Hutt River–Busselton–near Northcliffe) .... **H. balbakiae**

22: Shrubs single-stemmed. Leaves with apex strongly recurved or uncinate; apical point 0.3–0.5 mm long. Occurring on granite outcrops inland (Merredin–Lake King) .... **H. uncinatum**

21: Leaves with entire margins, apex ± straight or incurved; apical point absent or up to 0.5 mm long. Seeds 1.8–2.3 mm long

23. Single-stemmed or multi-branched, reseeder shrub up to 3 m high at full maturity. Leaves 0.6–1(–1.2) mm wide, about as wide as thick or slightly wider, the oil glands rather densely packed and often prominent. Stamens (20–)30–50 (Wongan Hills–Perth–near Ongerup) .... **H. suave**

23: Lignotuberous, resprouter shrub up to *c.* 1.5 m high. Leaves 1–6 mm wide, the floral leaves several times wider than thick, the oil glands usually sparser and less prominent than in *H. suave*. Stamens 18–30(–35)

24. Leaves (especially the floral ones) 1–2.3 mm wide; basal part broader than the upper third of the leaf (Badgingarra area–Albany area) .... **H. angustifolium**

24: Leaves 1.8–6 mm wide; basal part similar in width to the upper third of the leaf (Cataby–Mullering Brook area)... **H. × proliferum**

Descriptions of relevant species

Hypocalymma angustifolium (Endl.) Schauer, *Linnaea* 17: 241 (1843); *Leptospermum angustifolium* Endl., *Enum. Pl. Nov. Holl.* 50 (1837); *Hypocalymma angustifolium* Endl. var. *linophyllum* Schauer [as *linophylla*], *nom. illeg.* [= var. *angustifolium*], *Pl. Preiss.* 1: 112 (1844). *Type*: Swan River, Western Australia, *s. dat.* [prior to January 1834], *C.A. von Huegel s.n.* (*holo*: W 0047033).

Hypocalymma angustifolium subsp. Dandaragan plateau (S. Patrick 702 A), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub 0.4–1.2 m high, commonly 1–3 m wide, lignotuberous and therefore commonly with multiple stems from the ground, but sometimes recorded as single-stemmed or multi-branched near base (perhaps during fire-free periods). *Young stems* 4-angled and usually with 4 obtuse ridges protruding from the angles, glabrous. *Leaves* often reflexed on flowering stems, but otherwise varying from antrorse to patent, mostly at fairly widely spaced nodes. *Petioles* absent or poorly defined and less than 0.4 mm long. *Leaf blades* straight or slightly curved, very narrowly ovate-triangular to linear, mostly (or at least those subtending flowers) broadest at or near the base and tapering at a constant angle to an acute apex or tapering consistently in the distal half, 12–24 mm long, 1–2.3 mm wide, not thickened (but with margins often incurved) or moderately thickened distally, concolorous, entire, acute; abaxial surface convex or partially flat, grooved along the midvein, moderately densely dotted with numerous small oil glands; adaxial surface concave or partially flat, often more densely dotted than on abaxial surface; apical point 0.25–0.5 mm long. *Peduncles* borne at up to *c.* 18 (usually 6–11) widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1.2–2 mm long. *Pedicels* ± absent. *Flowers* 6–7.5 mm diam. *Hypanthium* 1.2–1.5 mm long, 3–3.5 mm diam., wrinkled-rugose; free part 0.3–0.5 mm long. *Sepals* very broadly or depressed ovate, 1.1–1.7 mm long, 1.7–2.5 mm wide, entire. *Petals* 2.3–3.2 mm long, white or pale pink, commonly turning deep pink with age, persistent, entire. *Stamens* 18–30(–35), in 1 or 2 series, united at base for 0.4–0.5 mm. *Longest filaments* 3–4 mm long, white. *Anthers* 0.35–0.5 mm long, pale yellow. *Ovary* 3-locular; summit prominently 3-ridged, becoming deep pink to red; ovules 1 per loculus, erect. *Style* 4–5 mm long; base deeply inset; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits c.* 2/3-superior, 2.5–2.7 mm long, 2.5–3 mm diam. *Seeds c.* 2.2 mm long, 0.8–1.2 mm wide, 1–1.2 mm thick, with a reticulate-pitted, medium brown testa; inner cavity *c.* 1.3 mm long; inner protrusion 1.1–1.5 mm long. (Figure 1A)

Diagnostic features. *Shrubs* 0.4–1.2 m high, with a lignotuber. *Young stems* 4-angled, glabrous. *Leaves* 12–24 mm long, the floral ones wider than thick and broader in the basal part than in the upper third, 1–2.3 mm wide, entire. *Petals* 2.3–3.2 mm long, white or pale pink, persistent. *Stamens* 18–30(–35). *Ovary* 3-locular; ovules 1 per loculus. *Style* 4–5 mm long; base deeply inset. *Seeds c.* 2.2 mm long.

Selected specimens examined. WESTERN AUSTRALIA: Guildford, Sep. 1901, *C. Andrews s.n.* (PERTH); no locality or date, *J. Drummond* 142 (MEL); 7 km N of Bullsbrook, 9 Aug. 1979, *R.K. Ellyard* 12 (CANB, PERTH); Badgingarra Rd, 6 km N from Dandaragan–Moora Rd, 30 Aug. 1984, *D.B. Foreman* 396 (AD, CANB, MEL, PERTH); 1.5 km E of Mogumber on Mogumber–Yarawindah Rd, 14 Sep. 1984, *D.B. Foreman* 709 (K, MEL, PERTH); Armadale, 17 Sep. 1920, *C.A. Gardner* 259 (PERTH); Mount Barker, Oct. 1898, *B.T. Goadby* 49 (PERTH); Jam Hill Reserve 25254, W of Moora, 27 June 1988, *E.A. Griffin* 4814 (PERTH); Reserve 12276, between Dandaragan and Moora, 11 Aug. 1988, *E.A. Griffin* 4883 (PERTH); granite outcrop off Mercer Rd, York. Transect 1, State Forest DEC A 47883, 5 Sep. 2008, *S. Gummow & T. Clack* EH 36 (PERTH); Blackboy Ridge Reserve, Chittering Rd, Chittering, 11 Aug. 2011, *G.J. Keighery* 17756 (PERTH); Bodhinyana Monastery, 216 Kingsbury Dr, Serpentine, 3 Aug. 2002, *B. Nyanatusita* 90 A (PERTH); 9.6 km N of Badgingarra Rd from Moora–Caro Rd at entrance to Strathmore, 13 Aug. 1991, *S. Patrick* 702 A (PERTH); Kalgan River, 21 Oct. 1991, *L.J. Pen* LJP 121 (PERTH); 13.5 km N of Regans Ford, along Brand Hwy, 6 Oct. 1982, *K.H. Rechinger* 58219 (PERTH); 17 km E of Frankland along the Cranbrook road at intersection with a road to Mount Barker, 8 Sep. 1976, *B.L. Rye* 76038 (PERTH); Norwood Reserve (Kalamunda Reserve 22502) off Norwood Rd, Maida Vale, 3.8 km WNW of Kalamunda, 23 Aug. 2003, *G. Smith* 58 (PERTH); above Moore River flats at Regans Ford, 31 Aug. 1966, *R.V. Smith* RVS 66/155 (MEL, PERTH).

Distribution and habitat. Extends from north of Badgingarra south-south-east to near Albany (Figure 2A), favouring lateritic or granitic habitats or associated with watercourses or swamps, often recorded with Jarrah or other eucalypts.

Phenology and insect associations. Flowers from late June to early October, with flowering beginning earlier in the north of the range. Mature fruits have been recorded in September and October. *Hypocalymma angustifolium* commonly has large floral galls, e.g. on *K.H. Rechinger* 58220, which also has the remnants of a *Callococcus* infection in the attached package.

Conservation status. As *H. angustifolium* is known from many localities, with some populations in nature reserves or other protected areas, it is not considered to be at risk.

Etymology. From the Latin *angustus* (narrow) and *-folius* (leaved) in reference to the narrow leaves of this species, although its close relatives *H. balbakiae* Tauss & Rye and *H. suave* usually have narrower leaves.

Vernacular names. White Myrtle. Noongar names for this or related species have been recorded as Koodgeed and Kudjidi (Abbott 1983; Hansen & Horsfall 2016).

Chromosome number. *2n = c.* 44, *fide* B.L. Rye, *Austral. J. Bot.* 27: 571 (1979). Voucher: *B.L. Rye* 76038.

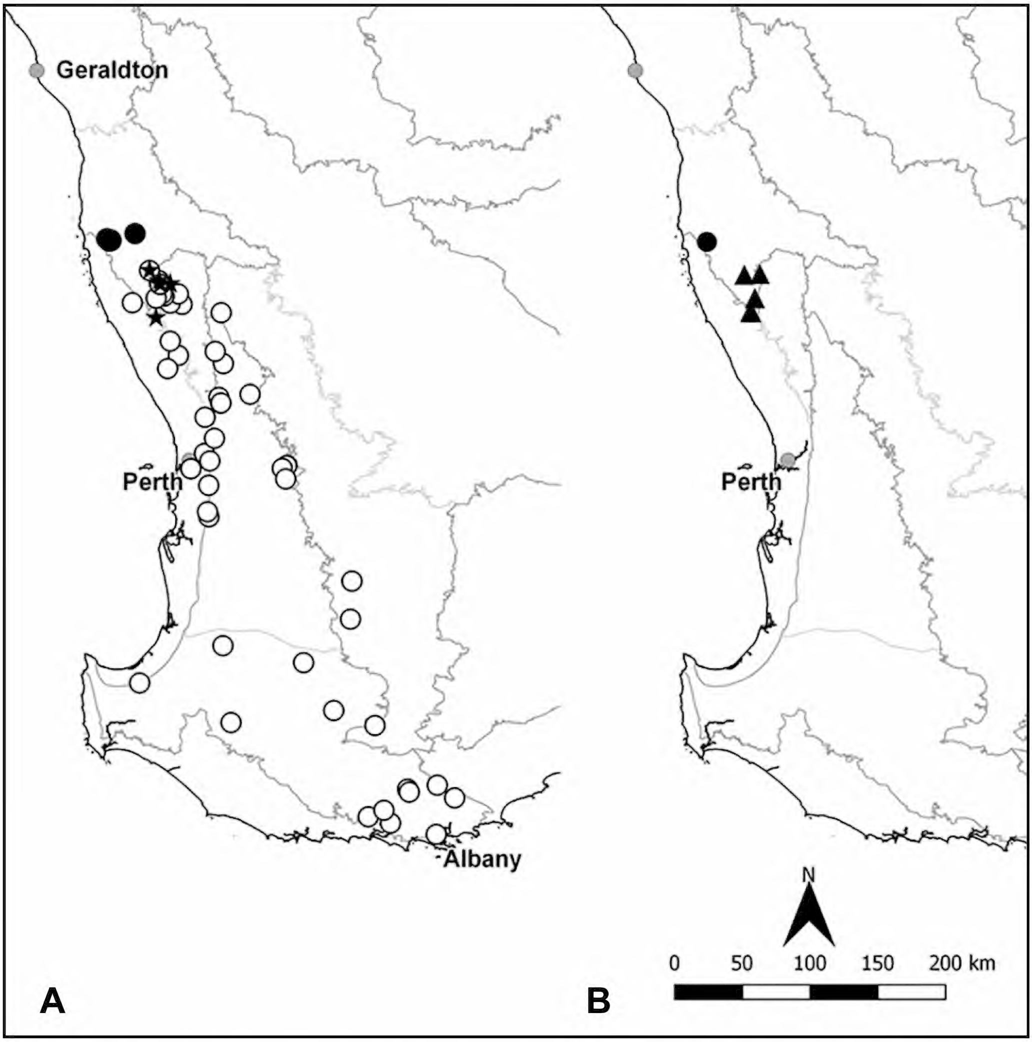

Figure 2. Distribution maps for *Hypocalymma* hybrids and two of the five parent species. A – *H. angustifolium* (○), *H.* × *linifolium* (★) and *H. tenuatum* (●); B – *H. tenuatum* × *H. xanthopetalum* (●) and *H.* × *proliferum* (▲).

Co-occurring species. *Hypocalymma angustifolium* hybridises readily with two species that have a similar flowering season, *H. tetrapterum* Turcz. and *H. lateriticola*, producing hybrid swarms (see discussion under their hybrids *H.* × *linifolium* and *H.* × *proliferum* respectively). It occupies higher or lower ground respectively than the other parent species. See the discussion under *H. xanthopetalum* for another possible hybrid involving *H angustifolium*.

Strid and Keighery (2002: 543) indicated that the flat-leaved variant of *H. angustifolium* (*E.A. Griffin* 4883), i.e. typical *H. angustifolium*, could be found not far from the variant described here as *H. balbakiae* (*E.A. Griffin* 4876) but was separated ecologically by its occurrence on upland sites rather than swampy sites. Whether the two taxa ever show strict co-occurrence is uncertain, but they are mounted together on a single herbarium sheet (now with two barcodes) of a very old collection (*Turner s.n.*, 1843), with *H. angustifolium* (PERTH 09484191) in more advanced flower than *H. balbakiae* (PERTH 02350580).

Hypocalymma angustifolium might also co-occur with *H. serrulatum*, as discussed under that species.

Affinities. The *H. angustifolium* complex includes *H. balbakiae*, *H. suave* and *H. uncinatum* Strid & Keighery, with considerable overlap in the ranges of the first three species but with *H. uncinatum* well separated geographically from the remainder of the complex.

What seems to distinguish *H. angustifolium* from *H. balbakiae* and *H. suave* best is that its leaves (or at least the ones subtending flowers) are more flattened throughout or at the base and usually taper continuously from the broad base to the apex or at least taper in the distal half, whereas in the two related species, the leaves are relatively uniform in width over most of their length. *Hypocalymma angustifolium* is similar to *H. balbakiae* in having a lignotuber but its leaves are shorter, less curved on average, and more commonly reflexed (on flowering stems) than in *H. balbakiae* and have smoother margins and a shorter apical point. It also has larger seeds and tends to have fewer stamens.

Hypocalymma suave and *H. uncinatum* differ from *H. angustifolium* in being single-stemmed and readily killed by fire, and *H. angustifolium* may have larger seeds than both these species, judging from the very few samples available for study. *Hypocalymma uncinatum* also differs from *H. angustifolium* in having crenulate leaf margins and an uncinate point to its leaves, while *H. suave* tends to have more densely glandular leaves and more numerous stamens.

Hypocalymma angustifolium may differ from the other members of its complex in having a tetraploid chromosome number, as a diploid number has been recorded for *H. suave*, but *H. balbakiae* and *H. uncinatum* have not yet been checked for chromosome number. A survey of chromosome number is needed for *H. angustifolium* to establish whether or not the tetraploid number occurs throughout its distribution.

Type collection. Huegel visited Fremantle, Darling Range and King George Sound between 27 November 1833 and 11 January 1834 (George 2009), well past the normal flowering time of *H. angustifolium*. Some specimens included in his collection might have been collected earlier by a resident collector, such as James Drummond, when more species were out in flower. Hence the true collector of the type specimen is not certain. Another possibility is that Huegel collected seeds and the collection was made from plants in cultivation in Europe.

Notes. The ability of *H. angustifolium* to regenerate from a lignotuber after fires is clearly evident from the specimen *K.R. Thiele* KRT 5581, which shows several dead, charred stems as well as new, more slender flowering shoots growing from the base of the plant. Additional material in mature fruit is needed for the species.

Hypocalymma balbakiae Tauss & Rye, *sp. nov.*

Type: Alison Baird Reserve, Bush Forever Area 387 (Greater Brixton St Wetlands), Kenwick, Western Australia, 30 September 2021, *B.L. Rye & C. Tauss* CT 8105 (*holo*: PERTH 09492488; *iso*: CANB, K, MEL, NSW).

Hypocalymma angustifolium subsp. Hutt River (S. Patrick 2982), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Hypocalymma angustifolium subsp. Swan Coastal Plain (G.J. Keighery 16777), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Illustrations. W.E. Blackall & B.J. Grieve, *How Know W. Austral. Wildflowers* 3A: 90 (1980); B.L. Rye & M.E. Trudgen, *Nuytsia* 18: 244, figure 3C (2008) [both as *H. angustifolium*].

Shrub 0.3–1.3(–2) m high, 0.5–2.5 m wide, with multiple stems from a lignotuber. *Young stems* 4-angled, glabrous. *Leaves* usually widely antrorse or patent, mostly widely spaced. *Petioles* absent or poorly defined and less than 0.5 mm long. *Leaf blades* moderately to strongly curved (incurved or recurved), linear or long-linear in outline, of fairly uniform width and thickness throughout their length, (20–)30–45 mm long, 0.6–1.3 mm wide, 0.3–1 mm thick, concolorous, with minutely crenulate margins, acute; abaxial surface deeply convex and usually flattened or grooved along the midvein in the basal half, rather sparsely to moderately densely dotted with numerous small oil glands; adaxial surface with a broad, v-shaped indentation along almost its full length; apical point 0.7–1.5 mm long, its tip often recurved. *Peduncles* borne at 5–26, usually widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1.5–2.2 mm long. *Pedicels* ± absent. *Flowers* 6–8 mm diam. *Hypanthium* 1.2–1.4 mm long, *c.* 3 mm diam., usually with a few large, prominent oil glands, often with some longitudinal ribs or somewhat rugose; free part 0.25–0.5 mm long. *Sepals* very broadly or depressed ovate, 1.3–1.8 mm long, 2.2–2.8 mm wide, scarious, often purple- or pink-tinged, entire. *Petals* 2.3–3.3 mm long, white or rarely pale pink at anthesis, often becoming deep pink to red with age, persistent. *Stamens* (23–)30–45, in 2 series, united at base for 0.3–0.6 mm. *Longest filaments* 2.5–3.7 mm long, white. *Anthers* 0.3–0.5 mm long, pale yellow. *Ovary* 3-locular; summit prominently ridged, becoming deep pink to red; ovules 1 per loculus, erect. *Style* 3.5–4.5 mm long; base deeply inset; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits c.* 2/3-superior, 1.9–2.3 mm long, 2.5–3 mm diam. *Seeds* 1.4–1.8 mm long, 0.6–1 mm wide, 0.75–1.1 mm thick, with a reticulate-pitted, medium brown to very dark red-brown testa; inner cavity 0.7–0.8 mm long; inner protrusion 0.8–1.2 mm long. (Figure 1D)

Diagnostic features. *Shrubs* with a lignotuber. *Young stems* 4-angled, glabrous. *Leaves* moderately to strongly curved, (20–)30–45 mm long, thick, minutely crenulate along margins, with a broadly v-shaped adaxial surface. *Petals* 2.3–3.3 mm long, white or pale pink at anthesis. *Stamens* (23–)30–45. *Ovary* 3-locular; ovules 1 per loculus. *Seeds* 1.4–1.8 mm long.

Selected specimens examined. WESTERN AUSTRALIA: *c.* 600 m W of Seaton Ross Rd on Corbalup Rd, *c.* 27 km ENE of Manjimup, 29 Oct. 1996, *A.R. Annels* ARA 5802 (PERTH); 26 km from Wanneroo Rd (near Yanchep), towards Gingin, 8 Oct. 1981, *L.A. Craven* 6965 (AD, CANB, MEL, PERTH); Northcliffe Forest Park, 8 Sep. 1991, *L. Graham* 776 (PERTH); Water Reserve 15538, between Dandaragan and Moora, 11 Aug. 1988, *E.A. Griffin* 4876 (PERTH); off Bunney Rd, Three Springs, 29 Aug. 2001, *S. Hamilton-Brown s.n.* (PERTH); Nine Mile Lake Nature Reserve, Herron Point Rd, WSW of Pinjarra, 22 Sep. 2005, *G.J. Keighery* 16777 (CANB, PERTH); Sabina River, just E of Sabina River bridge, Whicher National Park, 20 Oct. 2005, *G.J. & B.J. Keighery* 858 (PERTH); Ellis Rd, 1 km W of Old Coast Rd, Yalgorup National Park, 23 Aug. 2007, *G.J. & B.J. Keighery* 1222 (MEL, PERTH); Mt Roe National Park, 1 Nov. 2013, *R. Meissner, C. McCormack & M. Langley* 5023 (PERTH); 1.6 km from Yerina Spring Rd SE along Yerina Creek then *c.* 2.7 km NE along Hutt River, 2 Aug. 2007, *C. Page & G. Phelan* CP 170 (PERTH); Yerina Spring Rd, 2.3 km S of intersection with Ogilvie West Rd, 23 Sep. 1997, *S. Patrick* 2982 (PERTH); 2.5 km S of Brookton Hwy on Leona Rd, 30 Dec. 2004, *B.L. Rye, F. Hort & J. Hort* BLR 241206 (PERTH).

Distribution and habitat. Occurs along the west coast from near Hutt River south to Busselton, with somewhat inland locations extending south to near Northcliffe (Figure 3A), mainly in sandy wetland habitats on the margins of swamps and watercourses or mound springs, in low shrublands and sedgelands often dominated by taller shrubs or trees of *Melaleuca* or *Eucalyptus*.

Phenology and insect associations. Flowers mainly from late August to early November, with mature fruits recorded from October to February. Unlike *H. angustifolium* and *H. suave*, *H. balbakiae* does not appear to be prone to the development of large galls. It is susceptible to *Callococcus* (*B.L. Rye, F. Hort & J. Hort* BLR 241206) and small galls have been observed on *M.N. Lyons & S.D. Lyons* 3531.

Conservation status. Widespread and not considered to be at risk. One of its variants is listed as Threatened (Endangered) by the State and Commonwealth governments (Western Australian Herbarium 2018–;

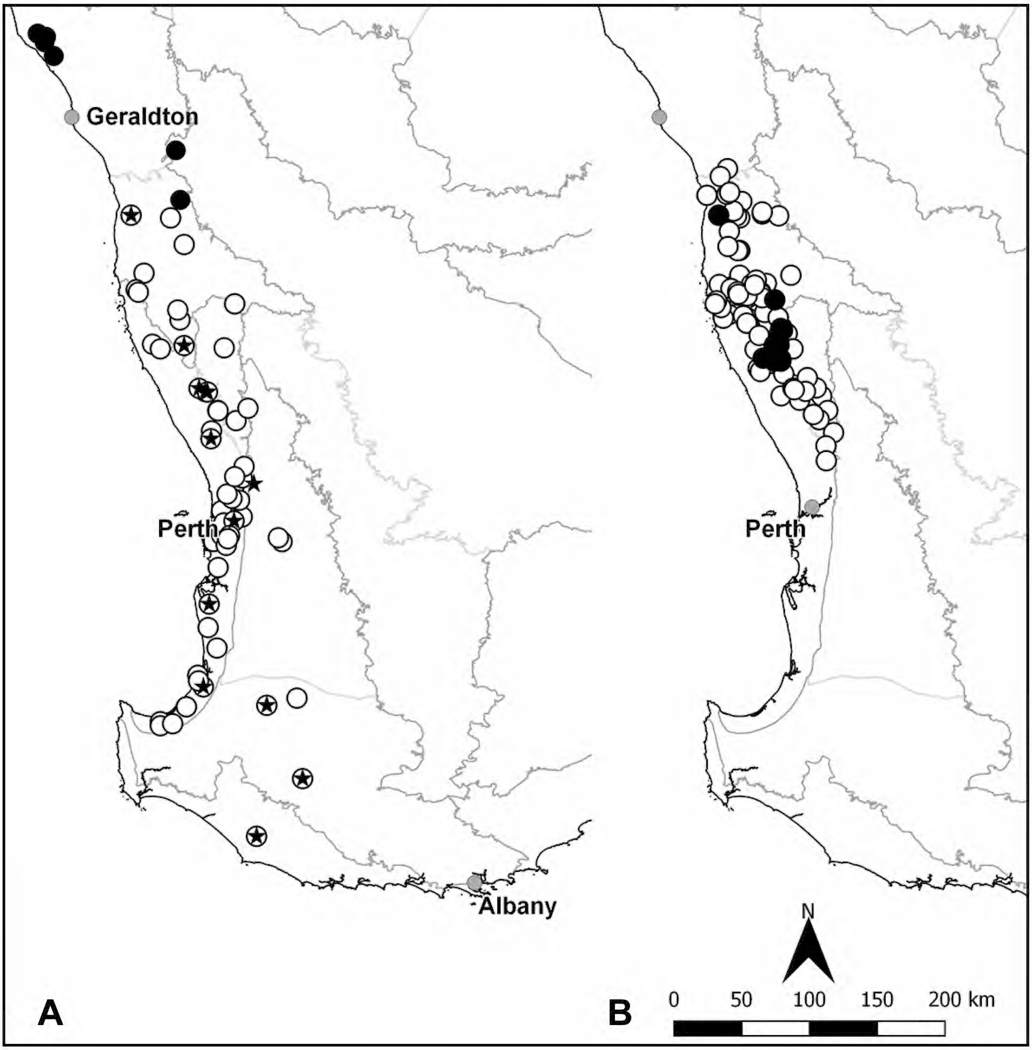

Figure 3. Distribution maps for three *Hypocalymma* species. A – *H. balbakiae* typical variant (○), Hutt River variant (●) and southern long-leaved specimens (★); B – *H. tetrapterum* (●) and *H. xanthopetalum* (○).

Department of the Environment 2022) under the name *H. angustifolium* subsp. Hutt River (S. Patrick 2982); a nomination will be prepared to the Threatened Species Scientific Committee for delisting.

Etymology. Named in honour of 'Granny' Balbak (1840–1907) a Whadjuk-Noongar, *boordiya yorga* (woman leader) and granddaughter of Yellagonga, who was the traditional owner of *Boorlo* (Perth). *Balbak* was known amongst the European colonists of her time (including the journalist Daisy Bates) as Balbuk, Fanny Balbuk, and even the trinomial Fanny Babulk Yooreel, that mimics European name structure. These names have remained in use until the present day, even though Balbak's Noongar descendants do not pronounce her name as Balbuk and usually avoid the other names.

Prior to colonization, Balbak's traditional country (*boodja*) including the current city centre of *Boorlo,* was a biodiverse landscape of rich food resources and many wetlands (Seddon 1972). The new *Hypocalymma* species was probably common there. As an adult, Balbak proudly wielded her superior, traditional knowledge, powers and social status in a setting where most of the Noongar lived in subjugation, fear and poverty. She actively resisted the usurpation of her country by the colonists and asserted her traditional ownership until the very end of her life (Pickering 2017; Ryan *et al.* 2019).

In her later years Balbak lived at Maamba Aboriginal Reserve, which was close to the Alison Baird Reserve in Kenwick, where H. balbakiae co-occurs with H. suave. At Maamba, the journalist and self-taught ethnographer Daisy Bates often interviewed Balbak and the other elderly Noongar incarcerated there, and recorded many details of the Noongar language, culture, plants and animals (Bates 1992). In 2006, the Federal Court of Australia ruled that the Noongar people held Native Title rights over the city of Perth and its surrounds. Though much of Bates' work is now considered highly inappropriate and paternalistic, it (and Balbak's information) played a part in securing the Noongar Native Title claim.

The use of the name Balbak in this paper complies with the pronunciation that is used for her name by the contemporary Noongar community and the spelling of this name, according to the orthography of the Noongar Dictionary (Whitehurst 1997) that was developed through a consensus of linguists and Noongar elders. Some examples of the pronunciation of Balbak are in the National Trust video (Pickering 2017) in which several *yorga* share their memories of the stories that their grandmothers (who were of the same generation as Balbak) told them, and her legacy. The Noongar place the emphasis in this name on the first syllable.

In forming the scientific epithet, there is a requirement for the Latin ending *iae* to be added to the epithet to indicate that the species is named after a woman. In the species epithet, *balbak* is written and pronounced according to the rules of the Noongar language and is also the correct Latin rendering of the authentic Noongar pronunciation. That is, both of the vowels of *balbak* are pronounced as the short sound 'a' (similar to the English, short sound 'u', as in hut.) Thus, *balbakiae* is pronounced in English as bul-buk-ee-ay.

Vernacular names. Balbak's White Myrtle. Noongar names for this or related species have been recorded as Koodgeed and Kudjidi in Abbott (1983) and Hansen and Horsfall (2016), where their use in traditional medicine is outlined.

Co-occurrence. Hybridisation was recorded by Strid and Keighery (2002: 543) between *H. balbakiae* (*G.J. Keighery* 13623) and *H. ericifolium* Benth. (*G.J. Keighery* 13625) at Capel Nature Reserve, with a number of hybrid plants (*G.J. Keighery* 13624) present. *Hypocalymma balbakiae* also co-occurs occasionally with *H. robustum*, which tends to flower later in the year, but one hybrid (*G.J. Keighery*

13435) between these two taxa has been collected from near Busselton.

Co-occurrence that has not resulted in hybridisation has been under study by two of us (CT and BLR) at a swamp in Kenwick, where *H. balbakiae* (*B.L. Rye & C. Tauss* CT 8105) and *H. suave* (*C. Tauss* 6838) grow somewhat intermixed in a very narrow zone, usually with *Pericalymma elliptica*, on the lower slopes of sand dunes adjacent to muddy flats. Here, *H. balbakiae* also extends into the somewhat deeper sand upslope of *H. suave* but does not grow with *H. suave* on the muddy flats. The two species have different flowering periods, although there must occasionally be an opportunity for cross-pollination to occur. *Hypocalymma suave* usually begins to flower in late June or July, reaches its peak of flowering in August and is in fruit in September or October, whereas *H. balbakiae* begins flowering later, usually reaching its peak in mid September. A fire in January 2007 destroyed the above-ground parts of *H. balbakiae*, which resprouted later in the year from a lignotuber, whereas the single-stemmed *H. suave* was killed and regenerated from seed.

Affinities. This member of the *H. angustifolium* complex is late-flowering and tends to have the longest and most curved leaves, with the v-shaped adaxial surface one of its more important diagnostic characters. It is possibly closest to the allopatric *H. uncinatum*, which it resembles in having minutely crenulate margins to the leaves and small seeds. *Hypocalymma uncinatum* is taller than *H. balbakiae* and single-stemmed and its leaves are more likely to have prominent oil glands and to be somewhat compressed.

See differences noted under *H. angustifolium* and *H. suave*.

Variation. Strid and Keighery (2002: 543) noted that ‘Prostrate pink flowered populations with straight not curved leaves occur in the Jandakot area’, citing a specimen from Rowley Rd (*B.J. Keighery* 760B). Re-examination of this specimen shows that it is not fully prostrate, only low-growing, and has curved leaves and pale pink flowers. Thus the distinctiveness of this population is now considered less than it was previously.

In the north of its range, *H. balbakiae* is restricted to relatively low-lying parts of swamps and other very damp locations, whereas it may occur at a greater distance from the wettest parts of swamps in the higher-rainfall zones in the south of its range. In one southern locality where *H. balbakiae* occupies the higher ground, *H. ericifolium* occupies the lower ground of a swamp and hybrids occur between these two species (see above). Northern populations all appear to have at least 30 stamens. In the south of its range *H. balbakiae* tends to have fewer stamens on average.

The widespread typical variant of *H. balbakiae* extends from near Arrowsmith River south to near the south coast and is usually 0.3–1.3 m high, commonly becoming dormant after its late flowering season and, except in good seasons, mostly having shorter internodes and leaves shorter on average than in a less common variant that extends north to Hutt River (see Figure 3A). The northern variant, which was given the phrase name subsp. Hutt River, is restricted to particularly damp habitats, such as mound springs, and is often taller, 1.3–2 m high, tending to grow throughout the year and produce long internodes and long leaves mostly 30–45 mm long. However, there are some occurrences of plants up to 2 m high (e.g. *D.G. Bright* ABC 02) further south, and some specimens have leaves up to 45 mm long in damp habitats further south too (see Figure 3A), especially near the Moore River (e.g. *S. Patrick* 1301), with no clear separation in their morphology. The fragmented distribution of such plants is likely to be associated with considerable genetic distance between the populations but low genetic variation within populations. The origin of each occurrence may have been through completely independent response of neighbouring typical *H. balbakiae* populations to the very damp habitat, resulting in only a superficial resemblance in these isolated occurrences. Therefore it appears that subsp. Hutt River should be regarded as an ecological variant rather than as a distinct taxonomic entity and we elect not to recognise it as a new subspecies. Molecular studies could be very valuable in examining these variants and other taxonomic problems in the *H. angustifolium* complex.

Notes. An image of the contents of two loculi from a fruit of *H. balbakiae* (Figure 1D) shows on the right the typical appearance of an infertile seed (or chaff piece) with the entire testa markedly reticulate-pitted, including the abortive elaiosome. The somewhat larger, more normal-looking seed in the same image has a more whitish elaiosome with puffed-out testa cells distally but even this seed was found to lack a viable embryo. Similar-sized seeds on other specimens sometimes do contain a fully formed white embryo.

Hypocalymma jessicae Strid & Keighery, *Nord. J. Bot.* 22: 562–563 (2002). *Type*: middle and upper slopes, south-east side, East Mt Barren, Western Australia, 2 January 1983, *A. Strid* 21892 (*holo*: C *n.v.*; *iso*: B 10 0279312, G 00223370, K 000797339 & 000797340, MEL 2290296 & 2290297, MO *n.v.*, PERTH 01945130).

Shrub 0.3–1.2 m high, commonly 1.2–1.5 m wide, single-stemmed or multi-branched at the base. *Young stems* somewhat angular to terete, glabrous. *Leaves* antrorse to ± patent, mostly widely antrorse, densely arranged on young stems. *Petioles* usually clearly differentiated from the blade, 0.4–1.3 mm long, yellow-brown. *Leaf blades* straight or moderately curved, narrowly obovate to linear in outline, 5–15 mm long, 0.5–1 mm wide, 0.4–1 mm thick, concolorous, glabrous, entire; abaxial surface deeply convex, with a narrow groove along the midvein, usually with 2 main rows of oil glands on each side of midvein; adaxial surface shallowly concave or with a broader groove distally than on abaxial surface; apical point absent or rarely up to 0.2 mm long. *Peduncles* borne at 1–3(–5) crowded or moderately spaced nodes on each flowering stem, 1–2.5 mm long, mostly 2-flowered. *Bracteoles* caducous, 1.3–1.8 mm long. *Pedicels* 0.3–0.8 mm long. *Flowers* 8–10.5 mm diam. *Hypanthium* 1.3–2 mm long, 2.5–3.5 mm diam., pitted-rugose with each pit corresponding with an oil gland; free part 0.35–0.5 mm long. *Sepals* broadly or very broadly ovate, 1.1–1.6 mm long, 1.5–2.3 mm wide, entire. *Petals* 3–4 mm long, pale to bright pink, usually shed before fruit matures. *Stamens* 35–100, in 2 or 3 series, united at base for up to 0.8 mm. *Longest filaments* 4–5.5 mm long, pink. *Anthers* 0.35–0.4 mm long, yellow. *Ovary* 2-locular; summit prominently ridged across the top; ovules 1–4 per loculus, most commonly 1 or 3, erect. *Style* 3.5–5.5 mm long; base not inset; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits c.* 2/3-superior, 2.5–3.75 mm long, 3–3.5 mm diam. *Seeds* 1.6–2 mm long, 0.7–1.2 mm wide, 0.8–1.3 mm thick, with a deeply reticulate-pitted, medium brown testa; inner cavity 0.9–1.2 mm long; inner protrusion 1.1–1.3 mm long.

Diagnostic features. *Young stems* glabrous, densely leafy. *Petioles* 0.4–1.3 mm long, usually clearly defined. *Leaf blades* 5–15 mm long, about as thick as wide, entire. *Peduncles* 1–2.5 mm long. *Pedicels* 0.3–0.8 mm long. *Petals* 3–4 mm long, pale to bright pink, usually shed before fruit matures. *Stamens* 35–100. *Ovary* 2-locular; ovules 1–4 per loculus. *Style* 3.5–5.5 mm long; base not inset. *Seeds* 1.6–2 mm long.

Distribution and habitat. Occurs in the Ravensthorpe Ranges and Fitzgerald River National Park, in shallow sand on rocky outcrops, the parent rock often quartzite.

Phenology and insect associations. Flowers and fruits recorded all year. A few leaf-attached scales may be present, for example black scales produced by white fly larvae on *M. Hislop* 2201.

Etymology. Named after Jessica Strid, who assisted with locating this species while in the field with her father Arne Strid.

Vernacular name. Barrens Myrtle.

Affinities. Closely related to *H. asperum* Schauer, *H. elongatum* (Strid & Keighery) Rye and *H. strictum*, but differing from all three species in its more densely clustered leaves and in being more variable in ovule number. The leaves tend to be less sharply angled in *H. jessicae* than in related species and have a better defined petiole.

Notes. Most species of sect. *Hypocalymma* have a fixed ovule number of either one or two per loculus. A further three species have three ovules per loculus. Only two species, *H. sylvestre* Strid & Keighery with 3–5 ovules and *H. longifolium* F.Muell. with 8–11 ovules per loculus, are known to have variable ovule numbers apart from *H. jessicae*.

When *H. jessicae* was described by Strid and Keighery (2002), the stamen number was given as *c.* 50 and the ovule number as one per loculus, although one of the cited specimens (*K.R. Newbey* 3122 from near Thumb Peak) actually had three ovules per loculus. Recent collections from both north-east and south-west of Thumb Peak also have consistently more than one ovule per loculus, and sometimes have 80–100 stamens per flower. They also tend to have shorter leaves.

If there were a complete difference in ovule and/or stamen numbers between the typical variant and this new variant, we would consider them to be distinct species or subspecies. Instead, we regard them as insufficiently distinctive to warrant formal treatment at this stage. Both variants exhibit some variation in ovule number. As currently delimited, *H. jessicae* has ovule numbers that are variable, even within populations, but most commonly either one or three per loculus.

a. typical variant of **Hypocalymma jessicae**

Leaf blades 7–15 mm long, 0.5–1 mm wide, 0.4–1 mm thick. *Stamens* 35–65, in 2 series. *Ovules* 1(–3) per loculus, not consistently more than 2.

Selected specimens examined. WESTERN AUSTRALIA: top of large easterly gully SE of Annie Peak, 27 Mar. 2012, *S. Barrett* 2101 (PERTH); summit area of Mt Drummond, Fitzgerald River National Park, 31 Jan. 1986, *J.M. Fox* 86/124 (CANB, MEL, PERTH); East Mt Barren, 29 Aug. 1962, *C.A. Gardner* 14040 (PERTH); West Mt Barren, Fitzgerald River National Park, 10 Nov. 2011, *D.A. Rathbone* DAR 783 (PERTH); Mt Short, 10 miles [16 km] N of Ravensthorpe, 5 Nov. 1968, *J.W. Wrigley s.n.* (CANB, PERTH).

Distribution. As given for the species, but not known from the small area where the new variant occurs.

Conservation status. This variant does not appear to be under threat. It has a range *c.* 100 km long, with most of its populations in a large national park and the remainder also having some protection by their occurrence on hillsides in the Ravensthorpe Range.

Notes. For all populations except at East Mt Barren, the only ovule number recorded so far is one per loculus. In the East Mt Barren area, ovule number varies from one to three although most specimens or flowers still have only one ovule in each loculus. Perhaps the greater variability here is due to the specimens occupying a large area, part of which may not be far from a population of either the new variant of *H. jessicae* (although not so far recorded from that area) or *H. asperum*, introducing the possibility of hybridisation as the source of ovule number variability. Alternatively, it may just be a region where variability in morphology is common as a result of plant populations occurring over a range of altitudes and microhabitats.

b. new variant of **Hypocalymma jessicae**

Leaf blades 5–8 mm long, 0.7–1 mm wide, 0.8–1 mm thick. *Stamens* (40–)55–100, in 2 or 3 series. *Ovules* 2–4 per loculus, mostly 3 per loculus.

Selected specimens examined. WESTERN AUSTRALIA: S of Thumb Peak, Fitzgerald River National Park, 5 July 2011, *S. Barrett* 2080 (PERTH); Fitzgerald River National Park, rough track between Quoin Head and Whalebone Beach, immediately S of adjacent quartzite ridge, 13 April 2001, *M. Hislop* 2201 (K, MEL, PERTH); 1.5 miles [2.4 km] S of Thumb Peak, 21 March 1970, *K.R. Newbey* 3122 (PERTH); *c.* 1.6 km ENE of mouth of Dempster Inlet on Fitzgerald Beach, Fitzgerald River National Park, 22 Sep. 2011, *C. Tauss* 6200 (PERTH).

Distribution and habitat. Occurs between Dempster Inlet and the Quoin Head area of Fitzgerald River National Park, with all localities close to the coast but protected to some degree from the salt-laden winds.

Conservation status. This geographically restricted variant is only known from an area *c.* 20 km long, but its populations are all protected by being in a large national park.

Notes. A recent collection (*C. Tauss* 5760) has more numerous ovules than previously recorded for the species, with up to four ovules per loculus, and another recent collection (*S. Barrett* 2079) has much more numerous stamens, with up to 100 per flower. A consequence of this great variability in ovule number is that *H. jessicae* appears twice in the key to members of the section presented above.

The new variant has a tendency to have shorter leaves than the typical variant, but the westernmost populations of the 1-ovulate (i.e. typical) variant also have shorter leaves than normal, so leaf characters also fail to give a reliable separation of the two variants recognised here.

Hypocalymma lateriticola Rye & Keighery, *sp. nov.*

Type: Dandaragan, Western Australia, 24 August 1948, *C.A. Gardner* 9014 (*holo*: PERTH 01059386 [sheet 1 of 3], PERTH 01059394 [sheet 2 of 3], PERTH 02108429 [sheet 3 of 3]; *iso*: K, MEL).

Hypocalymma xanthopetalum var. Dandaragan (C.A. Gardner 9014), G. Paczkowska & A.R. Chapman, *West. Austral. Fl.: Descr. Cat.* p. 388 (2000); Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Hypocalymma sp. Dandaragan (C.A. Gardner 9014), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub commonly 0.2–0.3 m high, multi-stemmed at the base from a lignotuber. *Young stems* 4-angled, glabrous, each angle with a ridge that projects widely outwards (directly out from the margin of one surface and at right angles to the adjacent surface), often forming a narrow wing. *Leaves* widely antrorse to widely retrorse on flowering stems, antrorse on vegetative stems, fairly widely spaced, sessile, ± straight (not incurved or recurved), narrowly obovate or obovate, 15–18 mm long, 3.5–10 mm wide, concolorous or discolorous, acute or obtuse, with thickened margins entire or rarely with teeth less than 0.2 mm long; abaxial surface shallowly convex to flat, dotted with numerous tiny oil glands; adaxial surface shallowly concave to flat; apical point absent. *Peduncles* borne at 2–6(–8) usually widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 2–3.5 mm long. *Pedicels* ± absent. *Flowers* 9–11 mm diam. *Hypanthium* 1.7–2 mm long, 3.5–4 mm diam., dotted with numerous small, pustule-like oil glands, sometimes also longitudinally wrinkled; free part *c.* 0.5 mm long. *Sepals* very broadly or depressed ovate, 1.6–2.6 mm long, 3–3.5 mm wide, entire or denticulate. *Petals* 3–3.5 mm long, bright yellow, persistent. *Stamens* commonly 65–125, in 2 or 3 series, united at base for 0.25–0.4 mm. *Longest filaments* 4–5 mm long, yellow. *Anthers c.* 0.5 mm long, yellow. *Ovary* 3-locular; summit prominently 3-ridged; ovules 2 per loculus, erect. *Style* 4–5 mm long; base not inset; stigma with elongated papillae, *c.* 0.3 mm diam. (including papillae). *Fruits* not seen at maturity but immature ones up to 5 mm diam.

Diagnostic features. *Young stems* 4-angled, glabrous, each angle with a ridge that projects widely outwards. *Leaves* sessile, 15–18 mm long, 3.5–10 mm wide, usually entire. *Petals* 3–3.5 mm long, bright yellow, persistent. *Stamens* 65–125. *Anthers c.* 0.5 mm long. *Ovary* 3-locular; ovules 2 per loculus. *Style* 4–5 mm long; base not inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 21 Aug. 1953, *H.F. & M. Broadbent* 1288 *p.p.* (PERTH 07733143); 10 Sep. 1979, *G.J. Keighery* 2549 (CANB, PERTH); 26 Aug. 2015, *G.J. & B.J. Keighery* 2362 (PERTH).

Distribution and habitat. Occurs near Badgingarra and Dandaragan (Figure 4), one record from grey sand with lateritic pebbles and another from lateritic soil over clay in sedgeland on the margin of a *Eucalyptus drummondii* mallee/tall shrubland upslope.

Phenology and insect associations. Flowers recorded in August and September. Narrow terminal galls are present on *G.J. Keighery* 2549.

Conservation status. Listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), under the name *H.* sp. Dandaragan (C.A. Gardner 9014). This species is known from few collections over a range *c.* 30 km long.

Etymology. From the Latin *lateritius* (brick-red) and *-cola* (inhabitant), referring to its occurrence in lateritic soils.

Vernacular name. Dandaragan Myrtle.

Co-occurring species. A collection cited above, *H.F. & M. Broadbent* 1288, has material of both this species (now separated onto PERTH 07733143) and *H. xanthopetalum* (PERTH 01059378), suggesting that the two species were growing together. Two other species, *H. serrulatum* and *H. tetrapterum*, may slightly overlap in range, but there are no records of co-occurrence with *H. lateriticola.*

Hypocalymma angustifolium co-occurs and hybridises with *H. lateriticola* (see under *H.* × *linifolium*).

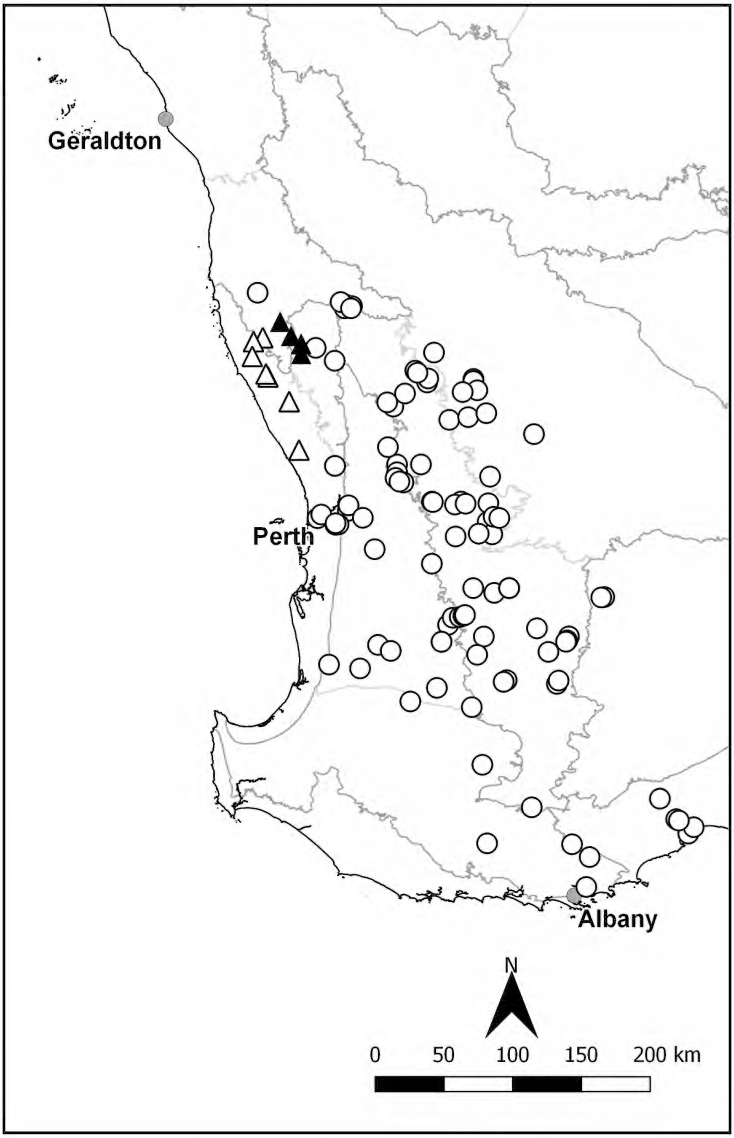

Figure 4. Distribution of *Hypocalymma quadrangulare* (△), *H. lateriticola* (▲) and *H. suave* (○).

Affinities. This species belongs to the *H. xanthopetalum* complex and is most similar to *H. quadrangulare*, which occurs closer to the coast and tends to be a taller shrub. The two taxa differ in the ridging of their young stems. In *H. lateriticola* the four marginal ridges of the stems extend out at right angles to the adjacent surface whereas *H. quadrangulare* has the ridges more rounded and scarcely protruding (with the four ridges incurved and often flattened over the surface between the angles). *Hypocalymma quadrangulare* has denticulate leaf margins with the teeth up to 0.3 mm long whereas the leaves of *H. lateriticola* are ± entire or have teeth less than 0.2 mm long.

Notes. This taxon is still quite poorly known. The type specimen *C.A. Gardner* 9014, on which both its phrase names were based, has the broadest leaves known in the *H. xanthopetalum* complex.

Three collections have entire or almost entire leaves, while the fourth (*H.F. & M. Broadbent* 1288) has minutely denticulate-ciliate margins to most leaves. In its leaf margins *H.F. & M. Broadbent* 1288 resembles *H. quadrangulare* but it is typical of *H. lateriticola* in its larger anther size and in its stem shape in transverse section.

Hypocalymma quadrangulare Rye & Keighery, *sp. nov.*

Type: west of Mimegarra Road [north of Lancelin], Western Australia [precise locality withheld for conservation reasons], 20 August 2011, *K.R. Thiele* 4190 (*holo*: PERTH 08430012; *iso*: CANB).

Hypocalymma sp. Nambung (R. Spjut & R. Smith s.n. 22/09/1992), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub commonly 0.3–0.7 m high (in cultivation recorded as 0.9 m high), multi-stemmed or multi-branched at the base. *Young stems* 4-angled, glabrous, each angle with a ridge that is incurved and often flattened over surface of stem. *Leaves* widely antrorse to widely retrorse on flowering stems, antrorse on vegetative stems, fairly widely spaced, sessile, ± straight (not incurved or recurved), narrowly obovate to obovate or ± oblong, 13–20 mm long, 3–8 mm wide, concolorous or discolorous, obtuse or acute, the margins scarious and denticulate with teeth up to *c.* 0.3 mm long; abaxial surface shallowly convex to flat, dotted with numerous tiny oil glands or the glands scarcely visible; adaxial surface shallowly concave to flat; apical point absent or rarely up to *c.* 0.25 mm long. *Peduncles* borne at 3–8 usually widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1.7–3 mm long. *Pedicels* ± absent. *Flowers* 8–10 mm diam. *Hypanthium* 1.7–2 mm long, 3–4 mm diam., often dotted with numerous small, prominent or pustule-like oil glands, longitudinally wrinkled; free part 0.4–0.6 mm long. *Sepals* broadly or very broadly ovate, 1.6–2.3 mm long, 2.3–3.5 mm wide, denticulate-ciliolate. *Petals* 3–3.5 mm long, yellow, persistent. *Stamens* 55–90, in 2 or 3 series, united at base for 0.3–0.7 mm. *Longest filaments* 3.5–5 mm long, yellow. *Anthers* 0.3–0.35 mm long, yellow. *Ovary* 3-locular; summit prominently 3-ridged; ovules 2 per loculus, erect. *Style* 3.5–5.5 mm long; base not inset; stigma with elongated papillae, 0.3–0.4 mm diam. (including papillae). *Fruits* *c.* 2/3-superior, 2.5–3 mm long, *c.* 4 mm diam. *Seeds* not seen at maturity, with a reticulate-pitted testa.

Diagnostic features. *Young stems* 4-angled, glabrous, each angle with a ridge that is incurved and often flattened over surface of stem. *Leaves* sessile, 13–20 mm long, 3–8 mm wide, denticulate. *Petals* 3–3.5 mm long, yellow, persistent. *Stamens* 55–90. *Anthers* 0.3–0.35 mm long. *Ovary* 3-locular; ovules 2 per loculus. *Style* 3.5–5.5 mm long; base not inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 5 Sep. 1978, *J. Dodd s.n.* (PERTH); cultivated material, 20 July 2005, *B.L. Rye & M.E. Trudgen* BLR 250707 (K, PERTH); 22 Sep. 1951, *N.H. Speck s.n.* (PERTH); 22 Sep. 1992, *R. Spjut & R. Smith s.n.* (PERTH); 25 Sep. 2000, *G. Woodman* 51-1 (PERTH).

Distribution and habitat. Extends along the west coast from Nambung National Park south to Moore River State Forest (Figure 4), occurring in Spearwood sands in *Banksia* woodlands or in shrublands, sometimes with *Eucalyptus todtiana* or *Conospermum* dominant, sometimes on limestone.

Phenology and insect associations. Flowers from July to October. Fruits at least from September to November. A small gall, observed on *J. Dodd* '57' (PERTH 02353563), appears similar to those on *H. tenuatum* specimens.

Conservation status. Recently listed as Priority Three under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), as *Hypocalymma* sp. Nambung (R. Spjut & R. Smith s.n. 22/09/1992). This species is known from few collections over a range *c.* 100 km long. It is, or has been, in cultivation in Perth.

Etymology. From the Latin *quadri-* (four) and *angularis* (angled), referring to the quadrangular stems which distinguish it from the previously named species with yellow flowers.

Vernacular name. West Coast Myrtle.

Co-occurring species. Overlaps in range with three other *Hypocalymma* species, *H. serrulatum*, *H. tetrapterum* and *H. xanthopetalum*, but there are no records of co-occurrence. However, there is a possible hybrid with *H. angustifolium* (see under *H. xanthopetalum*).

Affinities. This species is very similar to *H. lateriticola*, which occurs further inland. Differences between the two species in shrub size, stems and leaves are described under the latter species. *Hypocalymma quadrangulare* also has smaller anthers and usually fewer stamens than *H. lateriticola*.

Notes. Specimens from the southern part of the distribution have narrower leaves on average than those occurring further north.

Hypocalymma serrulatum Strid & Keighery, *Nord. J. Bot.* 22: 550–551 (2002). *Type*: Badgingarra National Park, Western Australia, 8 April 1982, *G.J. Keighery* 4595 (*holo*: PERTH 02352737; *iso*: PERTH 01175807).

Hypocalymma sp. Badgingarra (G.J. Keighery 4595), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub 0.3–1.8 m high, width not recorded, probably single-stemmed at base. *Young stems* tending to be terete, glabrous. *Leaves* antrorse to patent or rarely some retrorse. *Petioles* absent or poorly defined, up to 0.8 mm long. *Leaf blades* linear in outline, 6–15 mm long, 0.8–1.3 mm wide, 0.5–0.8 mm thick, concolorous, serrulate or ciliolate on margins with teeth or cilia up to 0.2 mm long, acute; abaxial surface convex or deeply convex, with 1 or 2 main rows of oil glands on each side of midvein and usually 8–11 glands per row; adaxial surface shallowly to deeply concave or v-shaped, sometimes also grooved along the midvein; apical point 0.1–0.3 mm long. *Peduncles* borne at 1–6 nodes of each flowering stem, often with two clusters of flowers separated by several sterile nodes, very reduced, mostly 2-flowered. *Bracteoles* persistent, 2–3 mm long. *Pedicels* ± absent. *Flowers* 7–8 mm diam. *Hypanthium c.* 1.5 mm long, 3–4 mm wide, rugose in bud, becoming more wrinkled or smoother with small glands; free part 0.4–0.7 mm long. *Sepals* broadly or very broadly ovate, 1.5–2.2 mm long, 1.8–2.7 mm wide, entire. *Petals* 3–3.5 mm long, white or pink, persistent. *Stamens* 40–55, in 2 or 3 series, united at base for 0.3–0.4 mm. *Longest filaments* 3.5–5.5 mm long, white. *Anthers* 0.45–0.55 mm long, pale yellow. *Ovary* 3-locular; summit prominently 3-winged; ovules 1 per loculus, erect. *Style* 4–5 mm long; base inset between wing-like ridges but not into ovary; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits c.* 2/3-superior, 3.5–4 mm long, 4–5 mm diam., usually 1-seeded, somewhat 3-winged on summit, shed as a diaspore (indehiscent). *Seeds* 2.1–2.4 mm long, 1–1.1 mm wide, 1.1–1.4 mm thick, with a reticulate-pitted, medium brown testa; inner cavity 1.3–1.5 mm long; inner protrusion reduced to being entirely terminal to the hilum, 0.45–0.7 mm long.

Diagnostic features. Unique in having indehiscent fruits. Other important characters: ovary summit prominently 3-winged; seeds with inner protrusion reduced.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 18 Nov. 2010, *D. Coultas & J. Kelt* PE Opp 37 (PERTH); 9 July 2005, *G.J. & B.J. Keighery* 474 (CANB, PERTH); 30 May 1994, *S. Patrick* SP 1802 (MEL, PERTH); 9 May 1974, *B.L. Powell* 74152 (PERTH).

Distribution and habitat. Extends from near Hill River to south of Badgingarra National Park, in sand, sometimes over laterite in low-lying areas at the base of low hills, often in *Banksia* woodlands and with *Eucalyptus todtiana*.

Phenology and insect associations. Flowers recorded almost all year but mainly from March to July, with fruits recorded from August to January. Galls forming stem swellings are sometimes present as on *C. Menzel s.n.* (PERTH 02352753).

Conservation status. Listed as Priority Two under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–). This geographically restricted species extends for only about 20 km, or possibly about 60 km based on its oldest collection (*D. Young* Y78, in May 1967), but is protected in one large national park.

Etymology. From the Latin *serrula* (a small saw) and *-atus* (likeness to), referring to the margins of the leaves.

Vernacular name. Early Myrtle.

Co-occurring species. *Hypocalymma serrulatum* (*S. Patrick* SP 1587) is recorded with *H. 'angustifolium'*. Although there is no specimen to check the exact identity of the latter species, no specimens of *H. balbakiae* or *H. suave* have been recorded from this region, whereas there are several records of true *H. angustifolium* in the region, so the identification is probably correct as it stands.

Affinities. As there are no obvious close relatives for this very distinctive species, it would be a good candidate for DNA analysis to explore its affinities.

Notes. *Hypocalymma serrulatum* is unusual in tending to flower in autumn and winter, as other species flower mostly from late winter to early summer. It is self-fertile and self-pollination can occur by the stamens closing around the stigma (see *breeding system* section under the description of sect. *Hypocalymma*). This may be a unique breeding system in the genus.

See also the earlier discussion of the unique fruit of this species in the *seed dispersal* section under the description of sect. *Hypocalymma*. The reduced protrusion on the seeds in *H. serrulatum* is to be expected since the fruits are indehiscent and hence seed dispersal does not rely on an elaiosome being present.

Hypocalymma suave Lindl. [as *suavis*], *Edwards's Bot. Reg.* 30: misc. 27 (1844). *Type citation*: 'It was raised in the garden of the Horticultural Society from Swan River seeds' [Western Australia] (*holo*: K 000821999).

Hypocalymma angustifolium var. *verrucosum* Schauer [as *verrucosa*], *Pl. Preiss.* 1: 112 (1844). *Type*: near Albany, October 1840, *L. Preiss* 336 (*syn*: LD 1355057, MEL 655028).

Shrub usually 0.5–3 m high, 0.3–3(–4) m wide, single-stemmed at base (no lignotuber), often multi-branched near base; basal stem commonly 9–15 mm diam. but sometimes more than 100 mm diam. *Young stems* 4-angled, glabrous. *Leaves* antrorse to patent, at fairly widely spaced to close nodes. *Petioles* absent or poorly defined and up to 0.8 mm long. *Leaf blades* straight or somewhat curved (incurved or recurved), linear or long-linear in outline, of fairly uniform width and thickness for most of their length, 8–30 mm long, (0.6–)0.8–1(–1.2) mm wide, 0.7–0.9 mm thick, concolorous, with entire margins, acute; abaxial surface deeply convex and narrowly grooved along midvein, usually densely dotted with oil glands, which tend to be prominent; adaxial surface fairly flat to shallowly deepening toward the centre, also narrowly grooved along midvein; apical point 0.3–0.5 mm long. *Peduncles* mostly borne at 3–20 closely to fairly widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1.2–2.3 mm long. *Pedicels* ± absent. *Flowers* 7–8 mm diam. *Hypanthium* 1–1.5 mm long, 2.7–3 mm diam., somewhat wrinkled-rugose and with some large oil glands; free part 0.7–0.8 mm long *Sepals* broadly to depressed ovate, sometimes auriculate, 1.3–1.4 mm long, 1.6–2.3 mm wide, pink- or purple-tinged, entire. *Petals* 2.5–3.5 mm long, white, remaining white in fruit or rarely becoming partially pink, persistent, entire. *Stamens* 20–50, in 1 or 2 series, united at base for 0.4–0.5 mm. *Longest filaments* 4–4.5 mm long, white. *Anthers* 0.4–0.45 mm long, pale yellow. *Ovary* 3-locular; summit prominently 3-ridged, turning deep pink to red; ovules 1 per loculus, erect. *Style* 4–5 mm long; base deeply inset; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits* 1/2–2/3-superior, 2–3 mm long, 2.5–3 mm diam. *Seeds* straight, 1.9–2.2 mm long, 0.75–0.8 mm wide, 0.75–0.8 mm thick, with a reticulate-pitted, medium brown testa; inner cavity 1–1.3 mm long; inner protrusion 1.1–1.4 mm long. (Figure 5)

Diagnostic features. *Shrubs* 0.5–3 m high, without a lignotuber. *Young stems* 4-angled, glabrous. *Leaves* 8–30 mm long, (0.6–)0.8–1(–1.2) mm wide, not much wider than thick, entire. *Petals* 2.5–3.5 mm long, white, persistent. *Stamens* 20–50. *Ovary* 3-locular; ovules 1 per loculus. *Style* 4–5 mm long; base deeply inset. *Seeds* 1.9–2.2 mm long.

Selected specimens examined. WESTERN AUSTRALIA: 2 miles [3 km] N of Watheroo, 18 July 1962, *J.S. Beard* 1660 (PERTH); Brixton Street Wetlands, Kenwick, 4 July 2007, *K.L. Brown, G. Paczkowska & K. Clarke* KLB 659 (AD, PERTH); 0.5 km S along Brook Rd from Welshpool Rd, Wattle Grove, 27 July 1976, *A.M. George* 75 (PERTH); Bindoon Springs Rd, 2 km NE of Bindoon Dewars Pool Rd then on track SE for 3 km and then 200 m NE, Gallager Block, Julimar Conservation Park, 9 Sep. 2006, *F. Hort & J. Hort* 2854 (AD, CANB, PERTH); 200 m S along Alton Rd, Kenwick, 29 Aug. 1985, *N. Hoyle* 47 (CANB, K, PERTH); North Wagin Nature Reserve, 1 km N of Wagin, 8 Aug. 2013, *G.J. Keighery & B.J. Keighery* 2073 (PERTH); Kulin Rd Nature Reserve, SW of Kulin, 11 Sep. 2017, *G.J. & B.J. Keighery* 2616 (AD, BRI, NSW, PERTH); S of Ongerup, 7 Oct. 2008. *S. Oborne* 137 (MEL, PERTH); in a dip in Cunderdin–Minnivale Rd, 0.8 km N of Berry Rd, Minnivale Nature Reserve, S of Minnivale, 18 Oct. 2013, *B.L. Rye & R. Davis* DR 11 (PERTH); Badgin Rd, 3 km N of Doodenanning Rd, E of York, 10 Nov. 2008, *B.L. Rye, F. Hort, J. Hort* BLR 281113 (PERTH); start of Mt Matilda Walk trail, Wongan Hills, 20 June 2005, *I. Smith* 6 (PERTH); Maamba Rd near Bruce Rd, Wattle Grove, 1 Sep. 2013, *C. Tauss* 6860 (PERTH).

Distribution and habitat. Extends from Watheroo National Park south-east to near Beaufort Inlet (Figure 3B). *Hypocalymma suave* is an abundant and often dominant species in the vegetation of the Kenwick wetlands on the eastern side of the coastal plain near Perth. In the Darling Range *H. suave* has been recorded on laterite in open woodlands of *Eucalyptus wandoo*, Powderbark Wandoo, Marri

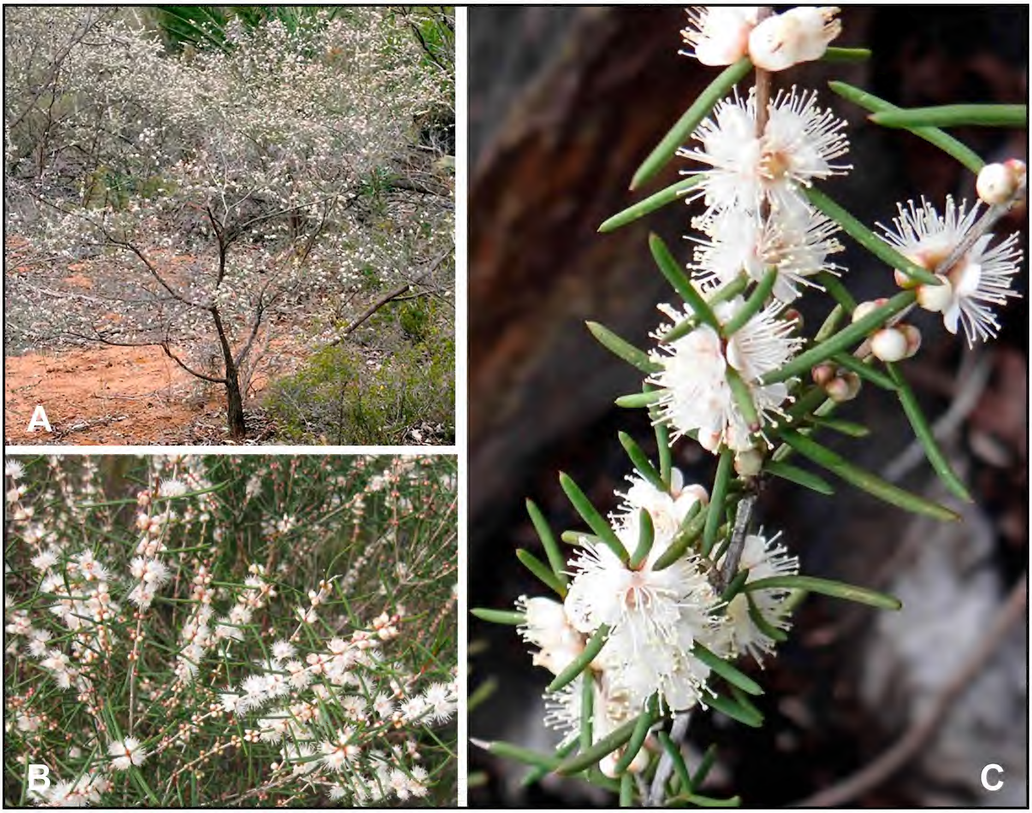

Figure 5. *Hypocalymma suave*. A – mature, single-stemmed specimen *c.* 2.7 m high at Julimar in 2006, B – in full flower at Kenwick on 21 July 2013; C – flowering branchlets with four buds or flowers per node, taken between Corrigin and Wagin on 8 August 2013. Images by Jean Hort (A), Cate Tauss (B) and Greg Keighery (C).

or other eucalypts. Inland collections are often also on laterite but they may also be from shrublands with *Allocasuarina*, often on sandplains or associated with granite.

Phenology and insect associations. Flowers mainly from late June to August. Fruits recorded from September to November. Many specimens have large flower galls and some have *Callococcus* infections, with both observed in a population at Kulin (*B.L. Rye* 290175).

Conservation status. This widespread species is not considered to be at risk.

Etymology. From the Latin *suavis* (sweet, pleasant, agreeable), described by Lindley (1844) as ‘a graceful greenhouse shrub, very sweet-scented, and altogether a very nice plant’. Lindley gave the epithet as *suavis* but it should be *suave* to agree with the gender of the genus. That correction was made by Lemaire (1845).

Vernacular name. Tall White Myrtle. Noongar names for this or related species have been recorded as Koodgeed and Kudjidi (Abbott 1983; Hansen & Horsfall 2016).

Chromosome number. $n = 11$, *fide* B.L. Rye, *Austral. J. Bot.* 27: 571 (1979). Voucher: *B.L. Powell* 74009.

Co-occurring species. Although the single-stemmed *H. suave* co-occurs with the lignotuberous *H. balbakiae* at Kenwick, it is ecologically separated to some degree and has an earlier flowering period. As there is no evidence of hybridisation and intergradation between the two taxa, they appear to be fully reproductively isolated from one another (see full details under *H. balbakiae*).

Similarly, *H. suave* (*K.R. Thiele* KRT 5586) co-occurs with *H. angustifolium* (*K.R. Thiele* KRT 5581) at a site visited in September 2019 in the Darling Range without any hybridisation. Again, it flowers earlier on average than the lignotuberous *H. angustifolium*, although there seems to be a greater overlap in flowering times in this case as there were still a few buds present on *H. suave* as the first flowers were opening on *H. angustifolium*. There may also be a difference in chromosome number, with *H. angustifolium* tetraploid and *H. suave* diploid, but more chromosome number records are needed to be sure that this is a consistent difference.

Affinities. This is a member of the *H. angustifolium* complex. It differs from both *H. angustifolium* and *H. balbakiae* in being single-stemmed and easily killed by fires. It regenerates readily from seed and in long fire-free periods is likely to be a much taller plant (see Figure 5A), the maximum heights recorded for two specimens being 2.7 and 3 m respectively. *Hypocalymma uncinatum* is also single-stemmed and has been recorded up to 2.5 m high but is distinguished from *H. suave* by its more eastern area of occurrence and by its hooked leaf tips and minutely crenulate leaf margins.

Like *H. angustifolium*, *H. suave* is susceptible to a form of attack that results in large galls, a feature that suggests these species are very close as it has not been recorded elsewhere except in a hybrid of the former species. *Hypocalymma angustifolium* (see notes under that species) differs in having more flattened floral leaves that taper from a broad base to an acute apex or at least taper for much of their length, and the two appear to differ in chromosome number (see above).

Hypocalymma suave lacks the minute serrations found along the leaf margins of *H. balbakiae* and does not have the broad v-shaped groove in the adaxial surface of its leaves, which also have less tendency to be patent.

Notes. This was one of the first species of *Hypocalymma* to have been in cultivation in Europe, having been grown in London during the 1840s. It was synonymised under *H. angustifolium* by Bentham (1867) and retained as such by subsequent authors, although Strid and Keighery (2002: 543) noted variation in leaf width and suggested that more than one taxon might need to be recognised within *H. angustifolium s. lat.*

Two varieties named by Schauer (1844) may both be synonyms of *H. suave*. Certainly, one syntype of *H. angustifolium* var. *verrucosum* matches *H. suave* but the other syntype, referred to in the protologue just as 'Drummond!', has not been examined.

Regrowth in the Kenwick population six years after a fire included a plant with a basal stem *c.* 15 mm in diameter; however, stems can be much thicker in very mature specimens, such as in the specimen shown in Figure 5A, which has a main stem more than 100 mm in diameter.

A population of plants growing on limestone at Mt Henry on the Swan River (*M. Cambridge* 37) has been identified for now as *H. aff. suave* as it resembles *H. suave* in leaf morphology but is distinctive in its habitat. It also appears to resemble *H. suave* in being single-stemmed as it was killed in a recent hot fire and regenerated by seed.

Hypocalymma sylvestre Strid & Keighery, *Nord. J. Bot.* 22: 558 (2002) [as *sylvestris*]. *Type*: Chittering, Western Australia [precise locality withheld for conservation reasons], 10 October 1998, *T. Palmer* 29 (*holo*: PERTH 05202825; *iso*: CANB 2290298, K 000797348, MEL 2290298, NSW 538091).

Hypocalymma sp. Chittering (T. Palmer 1), in G. Paczkowska & A.R. Chapman, *West. Austral. Fl.: Descr. Cat.* p. 387 (2000); Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub 0.4–0.8 m high, 0.4–1 m wide, base not recorded. *Young stems* almost 4-angled, glabrous. *Leaves* widely antrorse, densely arranged on young stems, sessile, straight or recurved, broadly ovate to cordate, mostly folded such that the leaf is v-shaped in TS but sometimes more flattened, 5–6 mm long, 4–5 mm wide, concolorous, with ciliate-laciniate margins, the largest cilia 0.25–0.45 mm long; abaxial surface with midvein thickened at base, dotted with numerous small oil glands on each side of midvein; adaxial surface folded inwards or hollowed along the midvein and with the margins recurved; apical point absent. *Peduncles* borne at 1–3 close nodes (resulting in a single dense cluster of flowers on each flowering stem), up to 1 mm long, 2-flowered. *Bracteoles* persistent, 3–4.5 mm long. *Pedicels* ± absent. *Flowers* 12–15 mm diam. *Hypanthium* 1.2–1.5 mm long, *c.* 3.5 mm diam., somewhat wrinkled-rugose and dotted with oil glands; free part 0.7–1.1 mm long. *Sepals* very broadly or depressed ovate, 2–3.5 mm long, 3–5 mm wide, entire. *Petals* 4–5 mm long, pale yellow, persistent. *Stamens* 100–200, in 2 or 3 series, united at base for *c.* 0.5 mm. *Longest filaments c.* 5 mm long, pale yellow. *Anthers* 0.5–0.65 mm long, yellow. *Ovary* 3-locular; summit prominently 3-ridged; ovules 3–5 per loculus, erect. *Style* 6–8 mm long; base not inset; stigma with low papillae or entire, 0.15–0.25 mm diam. *Fruits* 2/3–3/4-superior, 3.5–4 mm long, 5–5.5 mm diam. *Seeds* 1.8–2.3 mm long, 1–1.25 mm wide, 1.1–1.35 mm thick, with a deeply reticulate-pitted, yellow-brown testa; inner cavity 1.2–1.3 mm long; inner protrusion 1.3–1.5 mm long.

Diagnostic features. Distinguished from all other members of the genus by the combination of its high stamen numbers, of 100–200 per flower, and its 3-locular ovary with 3–5 ovules per loculus. Other important characters include: flowering stems with a single dense cluster of flowers; petals pale yellow; style 6–8 mm long, with base not inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 16 Sep. 2019, *C. Bourke* CB 201901 (PERTH); 18 Aug. 2006, *V. Clarke* VTC 663 (AD, PERTH); 23 Aug. 1998, *M. Hislop* 1088 (PERTH); 8 Sep. 2011, *M. Swinburn* 03 (BRI, PERTH).

Distribution and habitat. Occurs in the Chittering area of the Darling Range, on lateritic ridges in Powderbark Wandoo woodland.

Phenology and insect associations. Flowers mainly from August to October, rarely continuing to December, with mature fruits recorded in October and November. Some specimens have scales on the leaves, for example black scales formed by white fly larvae on *V. Clarke* VTC 664, but there are no galls or *Callococcus* scales.

Conservation status. Listed by as Threatened under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–; Department of the Environment 2022).

Etymology. From the Latin *sylvestris* (living in woods) as the species occurs in Powderbark Wandoo woodlands.

Vernacular name. Chittering Myrtle.

Co-occurring species. None recorded.

Affinities. A very distinctive species with broadly ovate to cordate leaves. It has no obvious close relatives, but is similar to members of the *H. xanthopetalum* group in having yellow flowers, high stamen numbers, more than 1 ovule per loculus and a non-inset style.

Notes. This species has more varied stamen and ovule numbers than previously recorded. Although stamen numbers were recorded in Strid and Keighery (2002: 558) as about 60 per flower, they have recently been found to be much higher, up to about 200 per flower. In fact *H. sylvestre* has the highest stamen numbers recorded in the entire tribe Chamelaucieae. Ovule numbers, previously recorded as two or three per loculus, are now recorded as a minimum of three and maximum of five per loculus.

The seeds examined for *H. sylvestre* were paler and more yellowish than those of the other species described in this paper but may not have attained their mature colour.

Hypocalymma tenuatum Strid & Keighery, *Nord. J. Bot.* 22: 545–546 (2002). *Type*: Mt Lesueur, Western Australia [precise locality withheld for conservation reasons], 24 July 1980, *E.A. Griffin* 2727 (*holo*: PERTH 02351315).

Hypocalymma sp. Lesueur (E.A. Griffin 1972) in Western Australian Herbarium, in *Florabase*, http://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub 0.2–0.7 m high, commonly 0.5–0.7 m wide, with a small lignotuber. *Young stems* 4-angled, densely papillose. *Leaves* antrorse to patent, often densely arranged on young stems. *Petioles* usually well defined, 0.2–0.4 mm long. *Leaf blades* straight or recurved, linear in outline, 6–9 mm long, 0.5–1.3 mm wide, 0.4–0.7 mm thick, concolorous, entire, with star-like prominent oil glands; abaxial surface deeply convex and with a groove along the midvein, with numerous prominent oil glands, each surrounded by a circle of papillae; adaxial surface ± flat; apical point 0.2–0.4 mm long. *Peduncles* borne at 4–15 widely spaced or fairly close nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 0.6–1.5 mm long. *Pedicels* ± absent. *Flowers* 5–6 mm diam. *Hypanthium* 1–1.3 mm long, *c.* 2.5 mm diam., wrinkled-rugose or with narrow longitudinal ribs; free part very reduced, *c.* 0.2 mm long. *Sepals* depressed ovate, 0.8–1.2 mm long, 1.5–2 mm wide, entire. *Petals* 2–2.5 mm long, white or pale yellow, persistent. *Stamens* 20–25, mostly in 1 series, united at base for up to 0.6 mm. *Longest filaments* 3–3.8 mm long, white or pale yellow. *Anthers* 0.25–0.3 mm long. *Ovary* 3-locular; summit prominently 3-ridged; ovules 1 per loculus, erect. *Style* 4.5–5 mm long; base deeply inset; stigma with low papillae or entire, less than 0.1 mm diam. *Fruits c.* 2/3-superior, 2.3–2.7 mm long, 2–2.5 mm diam. *Seeds* 1.8–2 mm long, 0.75–0.85 mm wide, 0.8–0.85 mm thick, with a shallowly reticulate-pitted, medium brown testa; inner cavity *c.* 0.9 mm long; inner protrusion 1–1.2 mm long.

Diagnostic features. *Young stems* 4-angled, densely papillose. *Leaf blades* 0.5–1.3 mm wide; apical point 0.2–0.4 mm long. *Petals* 2–2.5 mm long, white or pale yellow, persistent. *Stamens* 20–25. *Ovary* 3-locular; ovules 1 per loculus. *Style* 4.5–5 mm long; base deeply inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 31 Oct. 2002, *A. Crawford* ADC 278 (CANB, PERTH); 7 Nov. 2007, *A. Crawford* 1501 (K, PERTH);

24 Aug. 2002, *M. Hislop & F. Hort* MH 2725 (CANB, MEL, PERTH); 6 Oct. 1991, *S.J. Patrick* SP 865 (PERTH).

Distribution and habitat. Occurs from Lesueur National Park east to Warradarge (Figure 2A), with laterite in Wandoo woodland or associated with sandstone outcrops.

Phenology and insect associations. Flowers mainly from August to October. Mature fruits recorded from October to December. Small galls were observed on two specimens including *E.A. Griffin* 2619.

Conservation status. Listed as Priority Two under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–).

Etymology. From the Latin *tenuis* (slender) and *-atus* (indicating something completed), referring to the thin, drawn-out branches.

Vernacular name. Lesueur Myrtle.

Co-occurring species. This species is believed to have hybridised with *H. xanthopetalum* (see hybrid description below) but is not known to co-occur with any other species of *Hypocalymma*.

Notes. The voucher specimen for the phrase name *Hypocalymma* sp. Lesueur (E.A. Griffin 1972) is missing but other specimens such as *E.A. Griffin* 1971 and *E.A. Griffin* 1973 indicate that the material must have been collected not far from Mt Lesueur on 20 July 1979.

Hypocalymma tetrapterum Turcz., *Bull. Soc. Imp. Naturalistes Moscou* 35(2): 325 (1862). *Type*: Swan River [between Moore and Murchison Rivers, Western Australia, 1850–1851], *J. Drummond* 6: 68 [as 7: 68] (*holo*: KW 001001306; *iso*: BM 001015084, G 00223374 & 00223375, K 000821998, LD 1034350, MEL 104653, NSW 456457, W 18890153077).

Illustration. W.E. Blackall & B.J. Grieve, *How Know W. Austral. Wildfl.* 3A: 90 (1980).

Shrub 0.4–1.5 m high, spreading to erect, width not recorded, with a small lignotuber. *Young stems* 4-angled to narrowly 4-winged, densely papillose at the flowering stage but sometimes becoming ± smooth in fruit, glabrous, the papillae usually minute and obtuse but up to 0.15 mm long. *Leaves* appressed to patent, mostly antrorse, rather crowded to moderately spaced. *Petioles* absent or poorly defined and less than 0.5 mm long. *Leaf blades* straight (not incurved or recurved), very narrowly or narrowly obovate to narrowly oblong, 9–20 mm long, 2–7 mm wide, concolorous, obtuse, with entire or toothed incurved margins; abaxial surface convex, with numerous prominent oil glands, each gland surrounded by a circle of papillae; adaxial surface concave; apical point absent or up to 0.2 mm long. *Peduncles* borne at up to 20 (usually 4–14) widely spaced or rather crowded nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1.5–2 mm long. *Pedicels* ± absent. *Flowers* 7–9 mm diam. *Hypanthium* 1.1–1.3 mm long, *c.* 3 mm diam., rugose-wrinkled or with narrow longitudinal ribs; free part 0.4–0.6 mm long *Sepals* depressed ovate, 1.2–1.7 mm long, 2–3 mm wide, entire. *Petals* 3–4 mm long, white, persistent. *Stamens* 20–35, in 2 series, united at base for *c.* 0.5 mm. *Longest filaments* 3–4 mm long, white. *Anthers* 0.3–0.5 mm long, cream. *Ovary* 3-locular; summit prominently 3-ridged; ovules 1 per loculus, erect. *Style* 4–5 mm long; base deeply inset; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits c.* 2/3-superior, 2.5–3.5 mm long, 2.5–3 mm diam. *Seeds* 1.8–2.2 mm long, 0.7–0.8 mm wide, 0.75–0.8 mm thick, with a moderately deeply reticulate-pitted, medium brown testa; inner cavity 1–1.1 mm long; inner protrusion 1–1.3 mm long. (Figure 6)

Diagnostic features. *Young stems* 4-angled to narrowly 4-winged, densely papillose (when in flower). *Leaves* 9–20 mm long, 2–7 mm wide; apical point 0–0.2 mm long. *Petals* 3–4 mm long, white, persistent. *Stamens* 20–35. *Ovary* 3-locular; ovules 1 per loculus. *Style* 4–5 mm long; base deeply inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 19 Sep. 2017, *A.I. Craigie* 1713-001 (PERTH); 9 Dec. 2003, *A.D. Crawford* 499 (PERTH); 10 July 2005, *G.J. & B.J. Keighery* 486 (AD, CANB, MEL, PERTH); 31 July 1991, *S.J. Patrick* 658 (CANB, PERTH).

Distribution and habitat. Occurs mainly from Eneabba to south of Badgingarra, with an isolated northern record from north of Arrowsmith River (Figure 3B), in sand or heavier soils, often in open eucalypt woodlands.

Phenology and insect associations. Flowers from June to October, especially from July to September. Mature fruits recorded from August to December. One specimen, *S.J. Patrick* 664, appeared to have remnants of two small galls, possibly similar to those on *H. tenuatum*.

Conservation status. Listed as Priority Three under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–).

Etymology. From the Greek *tetra* (four) and *-pterus* (-winged), referring to the narrowly winged stems of the original collection.

Vernacular name. Papillose Myrtle.

Co-occurring species. Where this species co-occurs with *H. angustifolium*, hybrid swarms can be produced (see *H.* × *proliferum*).

Typification. As with other Turczaninow type specimens cited in this paper, the KW sheet is regarded here as the holotype because it was the only sheet available to Turczaninow. Strid and Keighery (2002) referred to the KW sheet as the lectotype but this lectotypification is invalid because the wording ‘here designated’ was omitted.

Notes. Drummond (1853) apparently referred to this taxon growing near Diamond Springs as ‘a white flowering and robust growing species, 5 or 6 feet high’ with leaves about as broad as in the yellow-flowered species.

Young stems are densely papillose as in *H. tenuatum* and both species also tend to have numerous prominent oil glands, each surrounded by a circle of papillae.

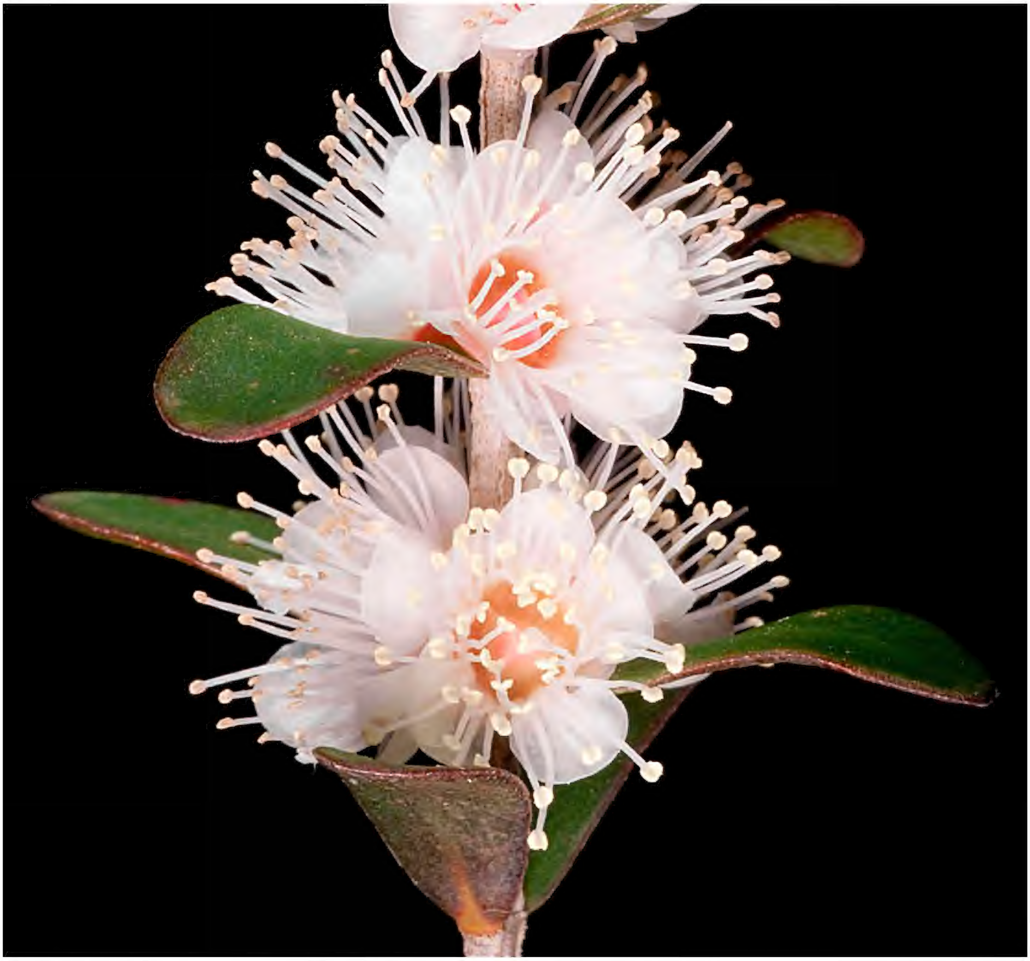

Figure 6. *Hypocalymma tetrapterum* showing a 4-angled, papillose stem, obovate leaves and white flowers with very pale anthers, taken by Kevin Thiele from *K.R. Thiele* 3988.

Hypocalymma xanthopetalum F.Muell., *Fragm.* 2: 29 (1860). *Type*: near Yatheroo [south of Dandaragan], Western Australia, 1859–1860, *A.F. Oldfield* 33 (*lecto*: MEL 104657, *fide* B.L. Rye, *Nuytsia* 28: 319 (2017).

Hypocalymma ciliatum Turcz., *Bull. Soc. Imp. Naturaliste Moscou* 35(2): 325 (1862). *Type*: Swan River [between Moore and Murchison Rivers, Western Australia, 1850–1851], *J. Drummond* 6: 66 [as 7: 66] (*holo*: KW 001001301; *iso*: BM 001015083, G 00223371, K 000821986, LD 1005390 & 1005454, MEL 104659, NSW 547529, W 18890153070).

Hypocalymma cuneatum Turcz. *loc. cit.* (1862). *Type*: Swan River [between Moore and Murchison Rivers, Western Australia, 1850–1851], *J. Drummond* 6: 67 [as 7: 67] (*holo*: KW 001001302; *iso*: BM 001015082, G 00223372, K 000821985, NSW 547530).

Illustration. W.E. Blackall & B.J. Grieve, *How Know W. Austral. Wildfl.* 3A: 91 (1980).

Shrub 0.1–0.8(–1.2) m high, 0.15–1.2 m wide, multi-stemmed from a lignotuber. *Young stems* ± terete, densely hairy; hairs minute or rarely a few of them *c.* 1 mm or more long. *Leaves* antrorse or patent, sessile, usually ± oblong, 12–25 mm long, 2–9 mm wide, scarcely thickened, concolorous or discolorous, with glabrous to densely ciliate recurved margins, often with a few small cilia towards the base, the cilia rarely up to *c.* 1 mm long, obtuse; abaxial surface concave or almost flat, dotted with numerous oil glands; adaxial surface tending to be convex rather than flat because of the recurved margins; apical point absent. *Peduncles* borne at up to *c.* 16 widely spaced to close nodes, but usually 2–5 moderately spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 2–3 mm long, often densely ciliolate. *Pedicels* ± absent. *Flowers* 8–10 mm diam. *Hypanthium* 1.5–2 mm long, 4–5 mm diam., wrinkled-rugose, sometimes with scattered oil glands visible but glands not very prominent; free part 0.5–0.8 mm long. *Sepals* very broadly or depressed ovate, 1.5–2 mm long, 2.3–2.8 mm wide, denticulate or partially ciliolate. *Petals* 3–4 mm long, pale to intense yellow, persistent. *Stamens* 80–135, in 3 series, united at base for 0.4–0.8 mm, which is up to *c.* 1/4 of their length. *Longest filaments* 3–4 mm long, pale to bright yellow. *Anthers* 0.35–0.55 mm long, yellow. *Ovary* 3-locular; summit prominently 3-ridged; ovules 2 per loculus, erect. *Style* 4–5 mm long; base not inset; stigma with elongated papillae, 0.2–0.4 mm diam. (including papillae). *Fruits* 1/2–2/3-superior, 2.5–3.5 mm long, 3.5–4 diam. *Seeds* 1.9–2.65 mm long, 1.3–1.4 mm wide, 1.1–1.3 mm thick, with a reticulate-pitted, brown testa; inner cavity 1–1.6 mm long; inner protrusion 0.8–1 mm long.

Diagnostic features. *Young stems* ± terete, densely hairy. *Leaves* sessile, 2–9 mm wide, entire to densely ciliate. *Petals* 3–4 mm long, pale to bright yellow, persistent. *Stamens* 80–135. *Ovary* 3-locular; ovules 2 per loculus. *Style* 4–5 mm long; base not inset; stigma with elongated papillae.

Selected specimens examined. WESTERN AUSTRALIA: 21 Aug. 1953, *H.F. & M. Broadbent* 1288 *p.p.* (PERTH 01059378); 2 miles [3 km] N of Regans Ford, 19 July 1978, *R.J. Cranfield 212* (CANB, K, MEL, PERTH); 2 km onto Nebru Rd from Three Springs, 23 Sep. 1968, *M.E. Phillips* WA/68 1515 (AD, BRI, CANB, L, PERTH); 5 miles [8 km] W of Mogumber, 18 Sep. 1973, *G.L. Webster* 18637 (DAV, NSW, PERTH); S foot of Mt Lesueur, 7 Oct. 1961, *J.H. Willis s.n.* (MEL).

Distribution and habitat. Extends from Mingenew south to Muchea (Figure 3B), occurring on sandplains in low heath.

Phenology and insect associations. Flowers mainly from July to September, with mature fruits recorded from July to October. Some specimens have heavy *Callococcus* infections (e.g. *J.R. Cannon* 341) or light ones as in *M. Rose* 111.

Conservation status. This moderately widespread species has numerous populations and is not considered to be at risk.

Etymology. From the Greek *xanthos* (yellow) and *-petalus* (-petalled).

Vernacular name. Yellow Myrtle.

Chromosome number. *n* = 11, *fide* B.L. Rye, *Austral. J. Bot.* 27: 571 (1979). Voucher: *B.L. Powell* 74005.

Co-occurring species. Natural hybrids with *H. tenuatum* have been reported from Mt Lesueur National Park (see hybrid below) and *H. xanthopetalum* probably co-occurs with other species such as *H. angustifolium* (see under that species).

A recently collected specimen (*B. Ellery* BE 705) is reported to be a hybrid between *H. angustifolium* and '*H. xanthopetalum*' at a locality where it was found among the two parent species; however, the parent species were not collected so which precise member of the *H. xanthopetlum* complex was present is unclear. The hybrid looks similar to *H.* × *linifolium* except that it has much more numerous stamens and could be a hybrid with *H. quadrangulare*.

Notes. The circumscription of *H. xanthopetalum* was reduced when Strid and Keighery (2002) removed the narrowest-leaved specimens from *H. xanthopetalum s. lat.* and described them as *H. gardneri* Strid & Keighery. *Hypocalymma gardneri* is distinguished by its more spindly habit and by its narrow leaves (usually 0.4–1.5 mm wide), although there is no clear distinction in leaf width between it and some narrow-leaved specimens still placed in *H. xanthopetalum*. The *H. xanthopetalum* complex appears to show continuous variation in leaf width, with much variation in leaf width often present on individual plants. For example, *T.E. Aplin & R. Coveny* 3132 has leaves 2–5 mm wide, some of its stems with all leaves broad and others with all leaves narrow or with narrow leaves at the base and broader leaves above. This problem in distinguishing *H. gardneri* could be partly caused by seasonal and other factors affecting leaf width or by the occurrence of hybridisation. The description given here for *H. xanthopetalum* applies to the broad- or moderately broad-leaved specimens primarily.

A further reduction to the circumscription of *H. xanthopetalum* occurred by the placement of all specimens with glabrous stems under phrase names, which are treated here as *H. quadrangulare* and *H. lateriticola*. Even so, *H. xanthopetalum* remains extremely variable, and warrants further study of its variants. Currently there is little mature fruiting material available.

Descriptions of hybrids

Hypocalymma tenuatum × H. xanthopetalum

Hypocalymma sp. Gairdner Range (C.A. Gardner 9091), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub c. 0.5 m high, width and base not recorded. *Leaves* appressed to patent, usually antrorse. *Young stems* 4-angled to almost terete, minutely hairy. *Petioles* 0.3–0.6 mm long. *Leaf blades* ± narrowly elliptic to linear, 7–12 mm long, 1.2–2 mm wide, not thickened but margins gently incurved, concolorous, minutely denticulate on the margins, acute; abaxial surface convex and with a narrow groove along the midvein, dotted with numerous oil glands; adaxial surface concave; apical point 0.25–0.3 mm long. *Peduncles* usually borne at 3–8 somewhat spaced to close nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1–1.5 mm long. *Pedicels* ± absent. *Flowers* 6–7 mm diam. *Hypanthium* 1.2–1.4 mm long, *c.* 3 mm diam., irregularly wrinkled and with some narrow longitudinal ribs; free part 0.3–0.4 mm long *Sepals* depressed ovate, 1–1.3 mm long, 2–2.3 mm wide, entire. *Petals* 2–2.5 mm long, yellow, persistent. *Stamens c.* 30, in 2 series, united at base for *c.* 0.3 mm. *Longest filaments c.* 3 mm long. *Anthers c.* 0.4 mm long. *Ovary* 3-locular; ovules 1 per loculus, erect. *Style c.* 3.5 mm long; base slightly inset; stigma with low to elongated papillae, *c.* 0.15 mm diam. (including papillae). *Fruits* unknown.

Diagnostic features. *Young stems* 4-angled to almost terete, minutely hairy. *Petioles* 0.3–0.6 mm long. *Leaf blades* ± flat, 7–12 mm long, 1.2–2 mm wide. *Petals* 2–2.5 mm long, yellow. *Stamens c.* 30. *Ovary* 3-locular; ovules 1 per loculus. *Style c.* 3.5 mm long; base slightly inset.

Specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons], 25 Aug. 1948, *C.A. Gardner* 9091 (PERTH, 2 sheets); 21 Aug. 1949, *C.A. Gardner* 9363 (CANB, PERTH).

Distribution and habitat. Recorded from Lesueur National Park (Figure 2B), on stony slopes.

Phenology and insect associations. Flowers recorded in August and September. No galls were observed on the few available collections.

Conservation status. This hybrid does not satisfy the requirements established by Thiele and Parker (2014) for listing with conservation priority. Previously it was listed as Priority Two (Smith & Jones 2018) as *H.* sp. Gairdner Range (C.A. Gardner 9091) but it will be delisted (Tanya Llorens pers. comm.).

Notes. This taxon is very poorly known. It was apparently collected twice by Charles Gardner from the same or almost the same locality, possibly even from the same plant, on Mount Lesueur in 1948 and 1949 respectively.

Two possible parent species, *H. tenuatum* Strid & Keighery and *H. xanthopetalum*, are recorded from the vicinity, and it is clear that the two Gardner specimens are intermediate in morphology between the putative parents in most characters but resemble each parent in at least two characters (Table 2). It is therefore concluded that *H.* sp. Gairdner Range (C.A. Gardner 9091) is the hybrid *H. tenuatum* × *H. xanthopetalum*. As the Gardner collections were made in what is now a national park, the hybrid may still be present in very small numbers. If not, the potential for it to reappear through cross-pollination between the parent species is still present.

Table 2. Comparison of three *Hypocalymma* taxa from Lesueur National Park.

Taxon	**H. tenuatum**	**H. tenuatum × H. xanthopetalum**	**H. xanthopetalum**
Flowering nodes / stem	4–15	3–8	2–5
Stem shape	4-angled	4-angled to terete	terete
surface	densely papillose	minutely hairy	hairy
Petiole length	0.2–0.4 mm	0.2–0.6 mm	absent
Leaf blade length	6–9 mm	7–12 mm	12–16 mm
width	0.5–1.3 mm	1.2–2 mm	2–5 mm
thickness	0.4–0.7 mm	scarcely thickened	scarcely thickened
mucro length	0.2–0.4 mm	0.25–0.3 mm	absent
Bracteole length	0.6–1.5 mm	1.5–2 mm	2–2.5 mm
Flower diameter	5–6 mm	6–7 mm	8–10 mm
Sepal length	0.8–1.2 mm	1–1.3 mm	1.5–2 mm
Petal length	2–2.5 mm	2–2.5 mm	3–3.5 mm
colour	white or pale yellow	yellow	yellow
Stamen number	20–25	*c.* 30	*c.* 80–135
filament length	3–3.8 mm	*c.* 3 mm	3–4 mm
anther length	0.25–0.3 mm	0.25–0.3 mm	*c.* 0.5 mm
Ovules per loculus	1	1	2
Style base	deeply inset	slightly inset	not inset

Hypocalymma × linifolium Turcz., *hybrid stat. nov.*

Hypocalymma linifolium Turcz., *Bull. Soc. Imp. Naturalistes Moscou* 35(2): 325 (1862). *Type*: Swan River [between Dandaragan and lower Murchison River, Western Australia, 1850–1851], *J. Drummond* 6: 65 [as 7: 65]; (*holo*: KW 001001303; *iso*: BM 001015085, E 00394754, G 00223369, K 000821997, LD 1034286 & 1035774, MEL 104602 (left piece only), NSW 456458, W 18890153069).

Illustration: W.E. Blackall & B.J. Grieve, *How Know W. Austral. Wildfl.* 3A: 90 (1980).

Shrub 0.3–0.6 m high, commonly 0.2–0.3 m wide, multi-stemmed at the base from a small lignotuber. *Young stems* 4-angled, glabrous, each angle with a ridge that projects at right angles to the adjacent surface. *Leaves* antrorse or patent, ± sessile, ± flat, narrowly ovate to very narrowly obovate or almost linear, 12–20 mm long, 2–4 mm wide, concolorous, acute, entire or denticulate; abaxial surface convex, with a groove along the midvein, dotted with numerous oil glands; adaxial surface concave; apical point 0.25–0.4 mm long. *Peduncles* borne at 5–15 widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, *c.* 2 mm long. *Pedicels* ± absent. *Flowers* 6–8 mm diam. *Hypanthium* 1–1.3 mm long, 2.5–3 mm diam., wrinkled-rugose and with some oil glands; free part *c.* 0.5 mm long. *Sepals* depressed ovate, 1.3–1.6 mm long, 2.5–2.8 mm wide, entire or denticulate. *Petals* 2.5–3 mm long, pale yellow, persistent. *Stamens* usually 20–35 in 2 series, united at base for *c.* 0.25 mm. *Longest filaments* 2.75–3 mm long. *Anthers* 0.4–0.45 mm long. *Ovary* 3-locular, prominently 3-ridged on summit; ovules 1 per loculus, erect. *Style* 3–3.5 mm long; base slightly inset or not inset; stigma with low papillae or entire, up to *c.* 0.1 mm diam. *Fruits* *c.* 2/3-superior, 2.5–3 mm long, *c.* 3 mm wide. *Seeds* (possibly not fully mature) *c.* 2.1 mm long, *c.* 1 mm wide, *c.* 1.1 mm thick, with a reticulate-pitted, medium brown testa; inner cavity *c.* 1.3 mm long; inner protrusion *c.* 1.5 mm long.

Diagnostic features. *Young stems* glabrous. *Leaf blades* 12–20 mm long, 2–4 mm wide, not very thick. *Petals* pale yellow. *Ovary* 3-locular; ovules 1 per loculus. *Style* base not or slightly inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 27 Sep. 1932, *W.E. Blackall* 2903 (PERTH); 26 Aug. 2015, *G.J. & B.J. Keighery* 2359 (AD, PERTH); Aug. 2015, *G.J. & B.J. Keighery* 2363 (CANB, PERTH); 23 Aug. 1968, *K.R. Newbey* 2784 (PERTH).

Distribution and habitat. Recorded from south of Badgingarra and north of Dandaragan (Figure 2A). Recorded in sand or in clayey soils associated with damp habitats, at one site with *Eucalyptus drummondii* trees over low heath.

Phenology and insect associations. Flowers and fruits recorded in August and September. Small galls similar to those on *H. quadrangulare* and *H. tenuatum* are present on *G.J. & B.J. Keighery* 2363.

Conservation status. Listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–) as *H. linifolium*. This hybrid appears to satisfy the requirements for this priority because of its long history of collection, its capacity to reproduce itself, and its occurrence in several populations with few or no specimens of the parent species present.

Etymology. From the Latin *linum* (flax, thread) and *-folius* (-leaved).

Typification. Strid and Keighery (2002) referred to the KW sheet as the lectotype but this lectotypification is not valid because the wording 'here designated' was omitted.

Notes. *Hypocalymma linifolium* Turcz. was reinstated in Rye (2017), where the possibility of its being a hybrid was raised. It has now been collected south of Badgingarra at a locality where it co-occurs with both parent species, *H. angustifolium* and *H. lateriticola*, although the majority of plants present are of the hybrid; a comparison of the three taxa at this locality is given in Table 3. *Hypocalymma* × *linifolium* has also been collected where one or both parent species were absent.

Hypocalymma × proliferum Keighery & Rye, *hybrid nov.*

Type: south of Cataby [precise locality withheld for conservation reasons], Western Australia, 28 August 1982, *G.J. Keighery* 5151 (*holo*: PERTH 01059432; *iso*: CANB 364603, K, MEL 0247681).

Hypocalymma sp. Cataby (G.J. Keighery 5151), in G. Paczkowska & A.R. Chapman, *West. Austral. Fl.: Descr. Cat.* p. 387 (2000); Western Australian Herbarium, in *Florabase,* https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Shrub commonly 0.5–1 m high, probably up to 1.6 m high, up to 1 m across, with a lignotuber. *Young stems* 4-angled, glabrous. *Leaves* antrorse or patent, ± sessile, very narrowly ovate or rarely narrowly obovate, 13–23 mm long, 1.8–6 mm wide, concolorous, with entire margins, acute or rarely obtuse; abaxial surface convex, with numerous prominent oil glands, each gland surrounded by a circle of papillae; adaxial surface concave; apical point absent or up to 0.2 mm long. *Peduncles* usually borne at 4–22 widely spaced nodes of each flowering stem, very reduced, mostly 2-flowered. *Bracteoles* persistent, 1.3–2 mm long. *Pedicels* ± absent. *Flowers* 7–8.5 mm diam. *Hypanthium* 1.1–2 mm long, *c.* 3 mm diam., wrinkled-rugose and with oil glands; free part 0.7–0.8 mm long. *Sepals* depressed ovate, sometimes auriculate, 1.3–1.5 mm long, 2.3–2.5 mm wide, entire. *Petals* 2.5–3 mm long, white, persistent. *Stamens* 22–35, in 2 series, united at base for *c.* 0.5 mm. *Longest filaments* 3–3.5 mm long. *Anthers* 0.3–0.5 mm long. *Ovary* 3-locular, prominently ridged on summit; ovules 1 per loculus, erect. *Style* 4–4.5 mm long; base deeply inset; stigma with low papillae or entire, up to *c.* 0.1 diam. *Fruits* unknown.

Diagnostic features. *Shrub* probably up to 1.6 m high. *Young stems* 4-angled, glabrous. *Leaves* 13–23 mm long, 1.8–6 mm wide, entire. *Petals* 2.5–3 mm long, white, persistent. *Stamens* 22–35. *Ovary* 3-locular; ovules 1 per loculus. *Style* 4–4.5 mm long; base deeply inset.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 16 Aug. 1973, *T.G. Hartley* 13930 (CANB, PERTH); 1 Aug. 1991, *S.J. Patrick* 662 (CANB, PERTH); 5 Sep. 2010, *K.R. Thiele* 3990 (PERTH).

Distribution and habitat. Occurs along the margins of watercourses in the Cataby and Mullering Brook areas (Figure 2B).

Phenology and insect associations. Flowers from June to October, especially from July to September. At least one specimen (*S.J. Patrick* 664 a) has *Callococcus* scales and another (*G.J. Keighery* 5151) has large flower galls.

Etymology. From the Latin *prolifer* (proliferating), referring to the frequent production of hybrids

Table 3. Comparison of *Hypocalymma* × *linifolium* with parent taxa at a locality south of Badgingarra.

Taxon and voucher	**H. angustifolium** *G.J. & B.J. Keighery* 2364	**H. × linifolium** *G.J. & B.J. Keighery* 2363	**H. lateriticola** *G.J. & B.J. Keighery* 2362
Position in landscape	low	intermediate	high
Flowering nodes / stem	8–16	5–15	2–6
Leaf length	12–15 mm	12–20 mm	15–23 mm
width	1–1.7 mm	2–2.8 mm	4–6 mm
apex shape	acute	acute	obtuse or acute
mucro length	0.25–0.4 mm	0.25–0.4 mm	0–0.25 mm
Bracteole length	1.2–1.5	*c.* 2 mm	2–3.5 mm
Flower diameter	6–7.5 mm	6–8 mm	*c.* 9 mm
Petal length	2.3–3.2 mm	2.5–3 mm	3–4 mm
colour	white or pink	pale yellow	yellow
Stamen number	*c.* 21	19–24	63–97
filament length	2.3–4 mm	2.75–3 mm	3–5.5 mm
anther length	0.25–0.3 mm	0.4–0.45 mm	*c.* 0.5 mm
Ovules per loculus	1	1	2
Style length	3.5–5 mm	3–3.5 mm	*c.* 5 mm
base	deeply inset	not or scarcely inset	not inset

and backcrosses.

Conservation status. This hybrid has been recognised for some time (see below) and was listed as Priority One (Western Australian Herbarium 1998–) as *H.* sp. Cataby (G.J. Keighery 5151). It satisfies at least two of the requirements for listing with conservation priority (see Thiele & Parker 2014). The only question is whether it is self-perpetuating or requires the presence of the parent species. Although no mature fruits have been found on the herbarium specimens, the hybrid is apparently fertile since back-crosses appear to be present and it may be more common than the parent species.

Notes. In 1990 Arne Strid labelled the PERTH sheet of *T.G. Hartley* 13930 as a probable hybrid between *H. angustifolium* and *H. tetrapterum*, and Strid and Keighery (2002: 543) noted that these two taxa possibly hybridised where their ranges overlapped. The occurrence of such hybrids has since been confirmed in the field by several collectors.

On a small tributary of Mullering Brook, specimens were collected in early September 2010 of the parent species, *H. tetrapterum* with obtuse, obovate leaves 6–7 mm wide (*K.R. Thiele* 3988), *H. angustifolium* with pointed, linear leaves *c.* 1 mm wide (*K.R. Thiele* 3991), and two representatives of a hybrid swarm, one with obtuse, narrowly obovate leaves 5–6 mm wide (*K.R. Thiele* 3989) and the other with more pointed, very narrowly ovate leaves 2–3 mm wide (*K.R. Thiele* 3990); Table 4 presents data from these four specimens.

Acknowledgements

Table 4. Comparison of two *Hypocalymma* hybrid specimens with specimens of the parent species collected in 2010 from the Muellering Brook area.

Taxon and voucher	**H. angustifolium** *K.R. Thiele* 3991	**H. × proliferum** *K.R. Thiele* 3990	**H. × proliferum** *K.R. Thiele* 3989	**H. tetrapterum** *K.R. Thiele* 3988
Position in landscape	high	intermediate	intermediate	low
Flowering nodes / stem	2–11	3–22	3–14	8–20
node separation	widely spaced	widely spaced	widely spaced	rather crowded
Stem 'wings'	absent	narrow	absent	narrow
Leaf shape	linear	very narrowly ovate	narrowly obovate	obovate
length	16–21 mm	20–23 mm	17–20 mm	12–15 mm
width	0.9–1.1 mm	2–3 mm	5–6 mm	6–7 mm
apex	acute to acuminate	acute	obtuse	obtuse
mucro length	0.3–0.6 mm	*c.* 0.2 mm	absent	absent
oil glands	small	small	large	large
Petal length	*c.* 2 mm	*c.* 2.5 mm	*c.* 3 mm	*c.* 3 mm
Stamen number	20–21	*c.* 35	*c.* 33	*c.* 30–35
filament length	*c.* 2.3 mm	*c.* 3 mm	*c.* 3 mm	*c.* 3 mm
anther length	*c.* 0.3 mm	*c.* 0.3 mm	*c.* 0.3 mm	0.45–0.5 mm

This project was supported by funding from the Australian Government's Australian Biological Resources Study National Taxonomy Research Grants Program. We are grateful to three First Nations elders, Marie Taylor, Corina Abraham and Vanessa Corunna, for their endorsement of the use of the name *balbakiae*. We also thank staff at MEL and K for the loan of specimens, including Laura Pearce for providing close-up images of the *Hypocalymma suave* type at K, to Mark Coode for confirming that there is no type material of *H. suave* at E, and Karina Knight and Shelley James for assistance with contacting overseas herbaria. We also thank Jean and Fred Hort for their observations, collections and images of *H. suave*, Kevin Thiele for his observations, collections and images, Alex Williams for the image of sterile seeds, Julia Percy-Bower and Steve Dillon for assistance with the distribution records and mapping, and Terry Macfarlane, Juliet Wege and Steve Hopper for their helpful comments.

References

Abbott, I. (1983). Aboriginal names for plant species in south-western Australia. *Forests Department of Western Australia Technical Paper* No. 5.

Bates, D. (1992). Edited by P.J. Bridge. *Aboriginal Perth (Bibbulmun Biographies and Legends)*. (Hesperian Press: Bayswater.)

Bentham, G. (1867). *Flora Australiensis*. Vol. 3. (Lovell Reeve & Co.: London.)

Brown, E.M., Burbidge, A.H., Dell, J., Edinger, D., Hopper, S.D. & Wills, R.T. (1997). *Pollination in Western Australia: a Database of Animals visiting Flowers*. Handbook No. 15. (Western Australian Naturalists' Club: Perth.)

Department of the Environment (2022). *Hypocalymma angustifolium* subsp. Hutt River (S. Patrick 2982) in Species Profile and Threats Database. Department of the Environment, Canberra. Available from: https://www.environment.gov.au/sprat. [accessed 23 August 2022].

Dodd, J., Heddle, E.M., Pate, J.S. & Dixon, K.W. (1984). Rooting patterns of sandplain plants and their functional significance. *In*: Pate, J.S & Beard, J.S. (eds) *Kwongan – plant life of the sandplain*. pp. 146–177. (University of Western Australia Press: Nedlands, Western Australia.)

Drummond, J. (1853). On the botany of the north western district of West Australia. *Hooker's Journal of Botany and Kew Miscellany* 5: 115–122.

George, A.S. (2009). *Australian Botanist's Companion*. (Four Gables Press: Kardinya, Western Australia.)

Hansen, V. & Horsfall, J. (2016). *Noongar Bush Medicine Plants: Medicinal Plants of the south-west of Western Australia*. (UWA Publishing: Crawley, Western Australia.)

Hopper, S.D. & Brown, A.B. (2001). Contributions to Western Australian orchidology: 1. History of early collections, taxonomic concepts and key to genera. *Nuytsia* 14: 1–26.

Houston, T.F. (2000). *Native Bees on Wildflowers in Western Australia*. Special Publication No. 2. (Western Australian Insect Study Society Inc.: Perth.)

Lamont, B. (1985). The significance of flower colour change in eight co-occurring shrub species. *Botanical Journal of the Linnean Society* 90: 145–155.

Lemaire, C.A. (1845). (ed.) *L'Horticulture Universel: Journal General des Jardiniers et Amateurs* Vol. 6. (H. Cousin: France.)

Lindley, J. (1844). Miscellaneous matter of the Botanical Register: 32. *Hypocalymma suavis*. *Edwards's Botanical Register* 30: misc. p. 27.

Pickering, G. (2017). *Fanny Balbuk Yooreel. Realising a Perth Resistance Fighter*. (National Trust: Western Australia.) https://www.youtube.com/watch?v=bpnZYm2-_PY

Ryan, J.C., Brady, D. & Kueh, C. (2019). Where Fanny Balbuk walked: re-imagining Perth's wetlands. *Media/Culture Journal* 18(6) https://doi.org/10.5204/mcj.1038 [accessed 23 August 2022].

Rye, B.L. (2010). A lectotype and new combination in *Hypocalymma* (Myrtaceae: Chamelaucieae). *Nuytsia* 20: 323–326.

Rye, B.L. (2013). A revision of the south-western Australian genus *Astartea* (Myrtaceae: Chamelaucieae). *Nuytsia* 23: 189–269.

Rye, B.L. (2017). Reinstatement of *Hypocalymma linifolium* and lectotypification of *H. xanthopetalum* (Myrtaceae: Chamelaucieae). *Nuytsia* 28: 317–320.

Rye, B.L., Keighery, G.J. & Barrett, M.D. (2022). Description of a new south-western Australian plant group, *Hypocalymma* sect. *Grandiflora* (Myrtaceae: Chamelaucieae: Astarteinae). *Nuytsia* 33: 233–249.

Rye, B.L., Wilson, P.G. & Keighery, G.J. (2013). A revision of the species of *Hypocalymma* (Myrtaceae: Chamelaucieae) with smooth or colliculate seeds. *Nuytsia* 23: 283–312.

Schauer, J.C. (1844). Myrtaceae RBr. *In*: Lehmann, J.G.C. (ed.) *Plantae Preissianae*. Vol. 1, pp. 96–158. (Meisner: Hamburg.)

Seddon, G. (1972). *Sense of Place*. (University of Western Australia Press: Perth.)

Sharr, F.A. (2021). *Western Australian Plant Names and their Meanings*. Fourth edition by A.S. George. (Four Gables Press, Kardinya, Western Australia.)

Slater, J.A. (1975). On the biology and zoogeography of some Lygaeidae (Hemiptera: Heteroptera) with special reference to the southwest fauna. *Journal of the Australian Entomological Society* 14: 47–64.

Slater, J.A. (1976). The biology, distribution and taxonomy of some Lygaeidae of southwest Australia (Hemiptera: Heteroptera). *Journal of the Australian Entomological Society* 15: 129–151.

Strid, A. & Keighery, G.J. (2002). A taxonomic review of the genus *Hypocalymma*. *Nordic Journal of Botany* 22: 535–572.

Thiele, K.R. & Parker, C.M. (2014). Treatment of hybrid taxa on the census of Western Australian plants. *Nuytsia* 24: 311–314.

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au/ [accessed 23 August 2022].

Whitehurst, R. (1997). *Noongar Dictionary*. Second Edn. (Noongar Language and Culture Centre (Aboriginal Corporation): East Perth, Western Australia.)

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 61–64
https://doi.org/10.58828/nuy01045
Published online 21 March 2023

Pterostylis segregata (Orchidaceae), a rare new species from south-west Western Australia

Garry Brockman[1] and Christopher J. French

Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[1]Corresponding author, email: garry.brockman@bigpond.com

SHORT COMMUNICATION

Pterostylis sargentii C.R.P.Andrews (1905) is commonly known as the Frog Greenhood due to its distinctive frog-like appearance. Together with the morphologically similar *Pterostylis occulta* G. Brockman & C.J.French (2021), these two species form the Frog Greenhood alliance. A third, distinct, restricted taxon has been found in the higher rainfall area of the south-west corner of Western Australia and is described here as new. This is the only member of the Frog Greenhood alliance known from this region.

Pterostylis segregata G.Brockman & C.J.French, *sp. nov.*

Type: Whicher Range, Western Australia [precise locality withheld for conservation reasons], 28 July 2021, *G. Brockman* GBB 4144 (*holo*: PERTH 09489282; *iso*: CANB, PERTH 09489290).

Terrestrial tuberous *herb* to 5–11(–14) cm tall. Plants solitary. *Basal rosette* absent in flowering plants; non-flowering plants forming a rosette of up to 10 spreading petiolate leaves, 12–15 mm long, 4–6 mm wide, lanceolate to broadly lanceolate, dull green with white veining. *Scape* to 90 mm tall, 1–2 mm diameter, dull greenish yellow; stem leaves 3–5, olive green, suberect, sessile, sheathing, 16–23 × *c.* 4 mm when flattened; floral bracts sheathing, acuminate, to 11–15 × 4–5 mm when flattened. *Flowers* 1–2(–3), 11–13 mm long, pale to olive-green with translucent striations, pink suffusions with aging; pedicels 8–10 mm long, *c.* 1 mm diameter, wiry; galea 7–9 mm long, bulbous, verrucose, shallowly curved at the base, mostly flat across the middle and deflexed to a short apex *c.* 1 mm long. *Dorsal sepal* 8–11 mm long including apical point *c.* 1 mm long, decurved, acute. *Lateral sepals* deflexed, conjoined in the upper two thirds, shallowly concave, elliptic when flattened, 6–7 × 2.5–3 mm, tapering abruptly to short lanceolate points 1.5–2 mm long, margins involute and glabrous. *Petals* appressed to the dorsal sepal along the upper margin, obscurely ovate when flattened, 7–9 mm long including short broad reddish apical point 0.5–1 mm long; upper margin with a line of closely spaced, unbranched, thickened, moniliform white trichomes on the internal surface, 0.4–0.7 mm long; lower proximal two thirds of margin extended, deflexed laterally, erose. *Labellum* irritable, on a claw 0.6–0.8 mm wide, upper lobes partially hidden in sinus in set position; laminae tri-lobed, papillate; central lobe triangular, 0.7–1 mm long, apex upturned, yellowish orange; lateral lobes ensiform, incurved, shorter than the central lobe, 0.5–0.7 mm long, yellowish orange; upper lobes arising from the base as erect tubular appendages 1–1.2 mm long, elliptic in cross section, obtuse, yellow to orange at base merging

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

to black in the distal half, papillate and hispidulous. Basal appendage absent. *Column* 8–9 mm long, erect, yellow to green, winged; wings orbicular, *c*. 2 mm long, incurved, opaque, upper medial surface with fine white cilia. *Ovary* narrowly ovoid, 6–8 × 2–3 mm. *Anther c*. 0.5 mm long, bluntly rostrate, yellowish green. *Pollinia* 0.7–1 mm long, yellow. *Stigma* ovate, 1.5 × 3 mm, translucent, yellowish. *Capsule* not seen. (Figure 1)

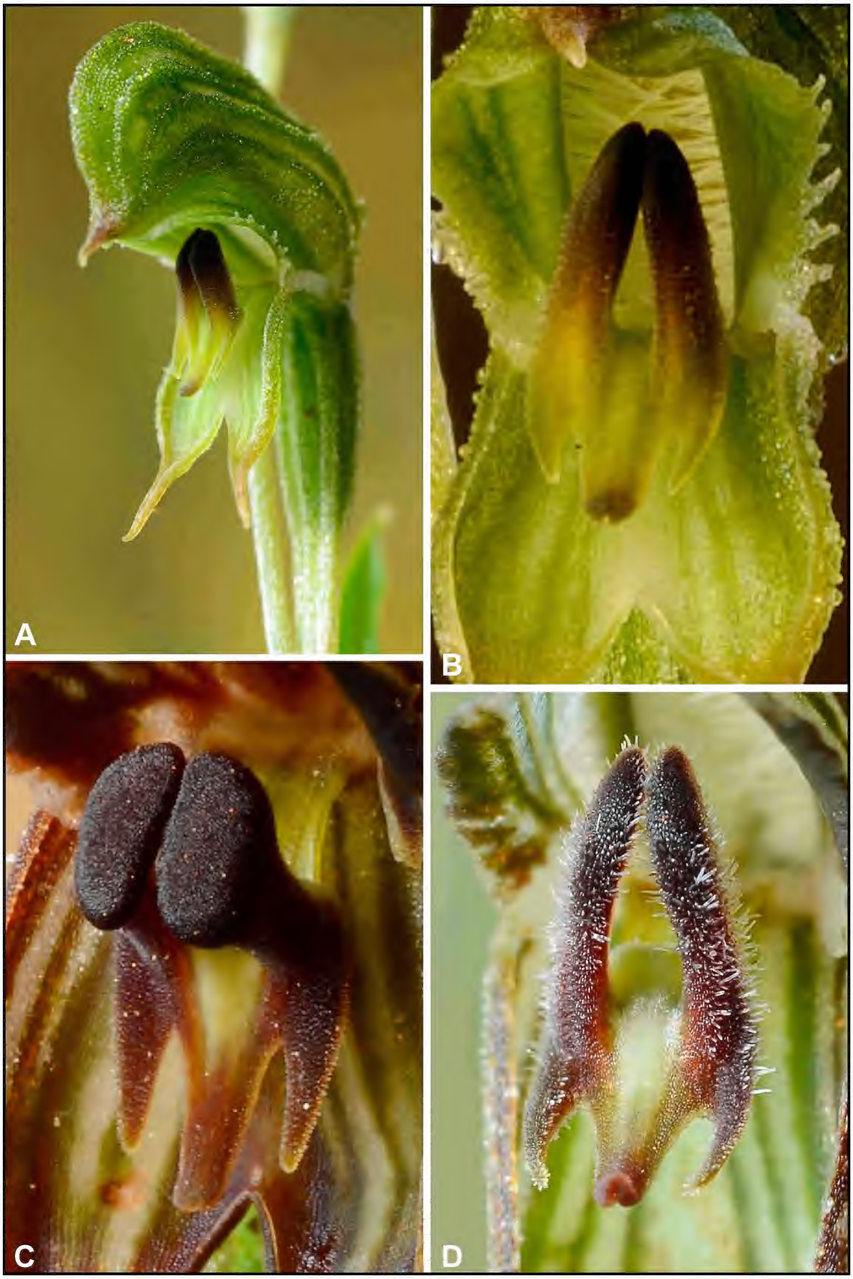

Figure 1. Comparison of *Pterostylis segregata* to allied species in the Frog Greenhood alliance. A – *P. segregata* flower *in situ* from the type location; B – *P. segregata* labellum; C – *P. sargentii* labellum; D – *P. occulta* labellum. Vouchers: *G. Brockman* GBB 4144 (A–B), *G. Brockman* GBB 4010 (C); *G. Brockman* GBB 4033 (D). Photographs: G. Brockman.

Diagnostic features. *Pterostylis segregata* can be distinguished from all other members of the genus by the following combination of characters: flowering and non-flowering plants dimorphic, flowering plants without a basal rosette of leaves, non-flowering plants with a basal rosette of up to 10 leaves that are lanceolate and dark green with white veining; inflorescence one- to three-flowered; flowers 11–13 mm long; galea with a single opening; synsepalum deflexed; labellum tri-lobed, the upper lobes tubular, elliptic in cross section, papillate and hispidulous, the basal appendage absent; medial petal surfaces with closely spaced, unbranched, thickened, moniliform barrier trichomes.

Other specimens examined. Whicher Range, Western Australia [locality withheld for conservation reasons], 19 July 2022, *G. Brockman* GBB 4345 (PERTH).

Phenology. Flowering from mid-July to early August.

Distribution and ecology. *Pterostylis segregata* is currently restricted to two geographically close locations in the south-west of Western Australia. It occurs in open patches of low mixed shrubland in jarrah marri forest, on sand over laterite.

Conservation status. To be listed as Priority One under Conservation Codes for Western Australian Flora (Tanya Llorens, pers. comm.). *Pterostylis segregata* is a recently discovered and poorly known species, currently known to comprise fewer than 50 flowering plants. It is conserved in state forest and requires immediate conservation resources.

Etymology. From the Latin *segregatus* (set apart or separated), alluding to the wide geographical separation of this species from other members of the Frog Greenhood alliance.

Common name. Shy Frog Orchid.

Affinities. *Pterostylis segregata* is morphologically similar to *P. occulta*. It is easily distinguished from that species by the erect, papillate, upper lobes of the labellum (reclined, densely ciliate for *P. occulta*). It has smaller flowers (11–13 mm long *cf.* 14–17 mm long in *P. occulta*), shorter sepal free points (1.5–2 mm *cf.* 2–3 mm in *P. occulta*) and extended petal inferior margins erose (entire for *P. occulta*). Basal rosette leaves are dull green with white veining *cf.* light lime-green in *P. occulta*.

Pterostylis segregata is morphologically similar to *P. sargentii*, however it has much smaller flowers (11–13 mm *cf.* 21–24 mm long in *P. sargentii*), much shorter sepal free points (1.5–2 mm *cf.* 4–6 mm in *P. sargentii*), a smaller labellum with tubular papillate upper lobes (bulbous and glabrous in *P. sargentii*), and the extended lower petal margins are erose (dentate in *P. sargentii*). Basal rosette leaves are dull green with white veining *cf.* light lime-green in *P. sargentii*.

The geographically closest collection of either *P. sargentii* or *P. occulta* is approximately 130 km east of the location of *P. segregata* in a dry wandoo woodland, a different habitat to the jarrah forest of the new species.

Acknowledgements

The authors would like to thank the Curator and staff of the Western Australian Herbarium for access to the specimens and comments on the preparation of this manuscript, and Roydan and Jan Read and Ray Walker for bringing this species to our attention and their ongoing field work and assistance.

Special thanks to Ben Lullfitz, Flora Conservation officer DBCA, Busselton, for his assistance in surveying of and invaluable conservation effort to protect this new species.

References

Andrews, C.R.P. (1905). Two new species of Orchideae from Western Australia. *Journal of the West Australian Natural History Society* 2(2): 57–58.

Brockman, G. & French, C.J. (2021). *Pterostylis occulta* (Orchidaceae), a new species from the south-west of Western Australia. *Nuytsia* 32: 51–54.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 65–92
https://doi.org/10.58828/nuy01046
Published online 21 March 2023

Four new species of *Amanita* sect. *Roanokenses* (Basidiomycota) from Western Australia

Elaine M. Davison[1,2,6], Danielle Giustiniano[3], Matt D. Barrett[4] and Katrina Syme[5]

[1]School of Molecular and Life Sciences, Curtin University, GPO Box U1987, Perth, Western Australia 6845
[2]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[3]School of Biomedical Sciences, Curtin University, GPO Box U1987, Perth, Western Australia 6845
[4]Australian Tropical Herbarium, James Cook University, PO Box 6811, Cairns, Queensland 4870
[5]24 Offer Street, Denmark, Western Australia 6333
[6]Corresponding author, email: e.davison@curtin.edu.au

Abstract

Davison, E.M., Giustiniano, D., Barrett, M.D. & Syme, K. Four new species of *Amanita* sect. *Roanokenses* (Basidiomycota) from Western Australia. *Nuytsia* 34: 65–92 (2021). Four species of *Amanita* Pers. are documented from Western Australia. *Amanita brunneola* E.M.Davison & Giustiniano is described from the Perth region. It is distinguished by its pale brown pileus, white universal veil, globose basal bulb, amyloid, cylindric spores and presence of clamp connections. *Amanita cretaceaverruca* E.M.Davison & Giustiniano is described from the Perth region and the southern jarrah forest. It is distinguished by its brown pileus, with a thick white warty universal veil, globose or ovoid basal bulb, amyloid, elongate spores and absence of clamp connections. *Amanita mallee* E.M.Davison, Giustiniano & M.D.Barrett is described from the Shire of Coolgardie. It is distinguished by its white pileus and universal veil, tapered basal bulb, amyloid, cylindric spores and abundant clamp connections. *Amanita validiuscula* E.M.Davison, Giustiniano & K.Syme is described from the wheatbelt and Yalgoo area. It is distinguished by its white pileus and universal veil, ivory lamellae, fusiform or tapered basal bulb, amyloid, ellipsoid spores and abundant clamp connections. Molecular analysis shows all these species are members of sect. *Roanokenses. Amanita brunneola, A. cretaceaverruca* and *A. mallee* form a clade with other species from Australia and New Zealand, which may indicate Gondwanan origin.

Introduction

Some of the most conspicuous mushrooms in Western Australia are species of *Amanita* Pers. This is a large, cosmopolitan genus of over 1000 described species, although only about 600 are well defined (Yang *et al.* 2018). *Amanita* spp. are important ecologically because most species are mycorrhizal with woody plants; they are important economically because some species are edible whilst others are poisonous (Cui *et al.* 2018).

In Australia the genus has been monographed by Reid (1980) and Wood (1997). Additional species and clarifications have been made by Miller (1991; 1992), Grgurinovic (1997), Davison (2011), Davison and Giustiniano (2020), Davison *et al.* (2013; 2015; 2017a; 2017b; 2020; 2021) and McGurk *et al.* (2016). Currently about 100 named species have been published, but many more await description.

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

Amanita is defined by the field character of a membranous or friable universal veil, the microscopic characters of bilateral lamella trama and acrophysalidic stipe trama, and the ontogenetic character of schizohymenial development (Bas 1969). However, molecular analyses are of increasing importance for identifying new species and determining relationships within the genus (Cui *et al.* 2018).

Amanita has recently been revised by Cui *et al.* (2018) using concatenated data sets of *nuLSU* (28S nuclear ribosomal large subunit rRNA gene), β-tubulin, *ef1-α* (elongation factor 1-α), and *rpb2* (RNA polymerase II) gene regions. They recognised three subgenera: *Amanita*, *Amanitina* (E.-J.Gilbert) E.-J Gilbert and *Lepidella* Beauseigneur. Most Australian species fall within subgenus *Amanitina* because they have amyloid spores, a bulb at the base of the stipe and are likely to be mycorrhizal. In the same paper six sections were recognised within *Amanitina*: sect. *Amidella* (E.-J.Gilbert) Konrad & Maubl., sect. *Arenariae* Zhu L.Yang, Y.Y.Cui & Q.Cai, sect. *Phalloideae* (Fr.) Quél., sect. *Roanokenses* Singer ex Singer, sect. *Strobiliformes* Singer ex Zhu L.Yang, Y.Y.Cui & Q.Cai, and sect. *Validae* (Fr.) Quél. These sections can be distinguished morphologically by differences in the pileus margin, form of the universal veil, and presence or absence of clamp connections.

Members of *Amanita* sect. *Roanokenses* are agaricoid, the pileus margin is non-striate and usually appendiculate, the universal veil on the pileus is usually fragile, often as pyramids, warts, floccules or patches, the bulb at the base of the stipe is globose to subglobose and not often radicating (Cui *et al*. 2018); however, in northern Australia many members of sect. *Roanokenses* have a radicating bulb. Clamp connections may be present, absent or variable.

In this paper we describe four new species from sect. *Roanokenses* that grow in association with woody native vegetation. All have a non-striate pileus margin, a universal veil on the pileus that breaks into small warts or patches, amyloid spores, two have a globose to subglobose bulb at the base of the stipe, and three of the four have clamp connections. We have used the *nuLSU* gene region to confirm their placement in this section because this is the only gene region available from GenBank for all type species of sections within subgenus *Amanitina*, and other gene regions (β-tubulin, *ef1-α, rpb2*) to look at their relationships with other local species. We have also looked at the variation in the nuclear ribosomal internal transcribed spacer (*ITS*) region, which has been used as a barcode marker for species discrimination within the Basidiomycota (Schoch *et al.* 2012). Hughes *et al.* (2013) found less than 2% base pair divergence between haplotypes within an individual from *Amanita* sect. *Validae*. However, the *ITS* region appears to be less useful in Australian amanitas. Davison *et al.* (2017a) found *ITS* sequences failed to separate three species from sect. *Phalloideae* that differ in spore shape and are geographically separated, whilst the base pair divergence between haplotypes from the same individual is 0.0–8.1% in sect. *Arenariae* (Davison *et al.* 2021).

Methods

Taxonomy. The methodology used for describing the macroscopic and microscopic characters largely follows Tulloss (2000). Colour names, including the colour of spores in deposit and other shades of white to cream (designated by the letters A–G), follow Royal Botanic Garden, Edinburgh (1969) while colour codes are from Kornerup and Wanscher (1983). In the descriptions of basidiospores (and basidia) the notation [x/y/z] denotes x basidiospores measured from y basidiomes from z collections. Biometric variables for spores follow Tulloss (2000), i.e. '**L** = the average spore length computed for one specimen examined and the range of such averages, **L′** = average spore length computed for all spores measured, **W** = the average spore width computed for one specimen examined and the range of such averages, **W′** = average spore width computed for all spores measured, Q = the length/

breadth for a single spore and the range of the ratio of length/breadth for all spores measured, **Q** = the average value of Q computed for one specimen examined and the range of such averages, **Q′** = the average value of Q computed for all spores measured'. Author citations follow Index Fungorum (http://www.indexfungorum.org/Names/Names.asp [accessed 9 Aug. 2022]).

Phylogenetics. DNA extraction, amplification and cloning of the *ITS* region, amplification of the *nuLSU*, *ef1-α*, *rpb2* and β-tubulin gene regions follow the methodology in Davison *et al*. (2017b). Sequence data were assembled with Geneious version 10.0.5 (Geneious undated). Additional sequences were accessed from GenBank (http://www.ncbi.nlm.nih.gov/ [accessed 4 July 2022]) (Tables 1 and 2).

Maximum likelihood phylogenetic trees were built using Mega version 5 (Tamura *et al.* 2011). The best model for each dataset was determined using the Model Function in MEGA (version 5, Tamura *et al.* 2011). The general time-reversible model (Travaré 1986) with invariant sites and gamma distribution rates was used to determine the placement of the undescribed species in subgenus *Amanitina* by using the *nuLSU* gene region. The Kimura 2-parameter model (Kimura 1980) with gamma distribution rates was used for the β-tubulin gene region, with invariant sites for the *rpb2* gene region, and with invariant sites and gamma distribution rates for the *ef1-α* gene region. The general time-reversible model (Travaré 1986) with invariant sites and gamma distribution rates was used for concatenated *nuLSU*, *rpb2 ef1-α* and β-tubulin gene regions. Bootstrap consensus trees were inferred from 500 replicates.

Results

Phylogenetics

The *nuLSU* is the only gene region available from GenBank for all type species of sections within subgenus *Amanitina*. These, together with additional species (Table 1) show *A. brunneola* sp. nov., *A. mallee* sp. nov., *A. cretaceaverruca* sp. nov. and *A. validiuscula* sp. nov. cluster within sect. *Roanokenses. Amanita brunneola* clusters with *A. pyramidiferina* D.A.Reid and *A. quenda* E.M.Davison in a well-supported clade (BS 99), *A. cretaceaverruca* clusters with the New Zealand species *A. australis* G.Stev. in a well-supported clade (BS 98), *A. validiuscula* clusters with an undescribed species *A.* sp-AUS20 from New South Wales in a well-supported clade (BS 99), and *A. mallee* clusters with *A. carneiphylla* O.K.Mill. in an unsupported clade (Figure 1).

Additional gene regions (*ef1-α*, *rpb2* and β-tubulin) are available for some collections within sect. *Roanokenses* (Table 2). Phylogenetic analysis of the *ef1-α* (Figure 2A), *rpb2* (Figure 2B) and β-tubulin (Figure 2C) gene regions, have a similar topology, to the phylogeny resulting from the concatenated *nuLSU*, *rpb2, ef1-α* and β-tubulin gene regions (Figure 2D), which shows the Australian and New Zealand species *A. australis, A. brunneola, A. carneiphylla, A. cretaceaverruca, A. mallee* and *A. quenda* form a well-supported clade (Figure 2D). Only the concatenated analysis shows very strong support for this clade (BS 100; Figure 2D). The other Australian and New Zealand species (*A. hiltonii* D.A.Reid, *A. pareparina* G.S.Ridl. *A. preissii* (Fr.) Sacc. and *A. validiuscula*) cluster with species from China (Figures 2A, 2B, 2C, 2D), indicating at least two lineages for these Australian and New Zealand species.

Table 1. Voucher information and GenBank accession numbers for *nuLSU* sequences from type of sections and other relevant collections used to place new species in subgenus *Amanitina*. Newly published sequences are shown in bold. *nuLSU*, nuclear ribosomal large-subunit rRNA region; NSW, New South Wales; SA, South Australia; WA, Western Australia.

Section	***Amanita*** **spp.**	Voucher number	Location	***nuLSU***
Amidella	*A. volvata* (Peck) Lloyd	KA12-1367	Gyeongbuk, Korea	KF245907
	A. brunneomaculata Zhu L.Yang, Y.Y.Cui & Q.Cai	HKAS 70032	Yunnan, China	MH486411
	A. lanigera Y.Y.Cui, Q.Cai & Zhu L.Yang	HKAS 89030	Yunnan, China	MH486621
	A. parvicurta Y.Y.Cui, Q.Cai & Zhu L.Yang	HKAS 101215	Yunnan, China	MH486745
Arenariae	*A. arenaria* (O.K.Mill. & E.Horak) Justo	PERTH 07586329, VPI679 (type)	City of Albany, WA	GQ925382
	A. wadulawitu McGurk, E.M.Davison & E.L.J.Watkin	PERTH 09144390	Shire of Serpentine-Jarrahdale, WA	MN918098
	A. peltigera	AD282185	Kangaroo Island, SA	MN900628
Phalloideae	*A. phalloides* (Vaill. ex Fr.) Link	HKAS75773	China	JX998060
	A. djarilmari E.M.Davison	PERTH 08776067	Shire of Cuballing, WA	KY977704
	A. marmorata (Cleland & E.-J. Gilbert) E.-J.Gilbert	PERTH 08690596	Shire of Denmark, WA	KY977711
Roanokenses	*A. roanokensis* Coker	FLAS-F-60892	Florida, USA	MH620252
	A. australis G.Stev.	JAC12865	New Zealand	MT862264
	A. avellaneifolia Zhu L.Yang, YY.Cui & Q.Cai	HKAS80011	Yunnan, China	MH486378
	A. carneiphylla O.K.Mill.	PERTH 08793530	City of Melville, WA	MN911351
	A. carneiphylla	PERTH 08793565	Shire of Cuballing, WA	**MN911352**
	A. carneiphylla	AD282179	Kangaroo Island, SA	**MN911353**
	A. elliptica Q.Cai, Y.Y.Cui & Zhu L.Yang	HKAS96797	Hainan, China	MH486488
	A. farinacea (Sacc.) Cleland & Cheel	AD-C4470	SA	HQ539692
	A. gymnopus Corner & Bas	HKAS89031	Yunnan, China	MH486583
	A. hiltonii D.A.Reid	PERTH 09004564	Shire of Mundaring, WA	MT364456
	A. hiltonii	PERTH 09004580	Shire of Manjimup, WA	MT364457
	A. hiltonii	PERTH 09004599	Shire of Cuballing, WA	MT364455
	A. manginiana Har. & Pat.	HKAS56933	China	KJ466438
	A. miculifera Bas & Hatan.	HKAS101425	Shenyang, China	MH486643
	A. modesta Corner & Bas	HKAS79688	China	KJ466440
	A. mumura G.S.Ridl.	PDD 82690	New Zealand	MT862255
	A. neo-ovoidea Hongo	HKAS89025	Yunnan, China	MH486656
	A. ochrophylla (Cooke & Massee) Cleland	AD-C49440	SA	HQ539717
	A. pareparina G.S. Ridl.	JAC13371	New Zealand	MT862271

Section	*Amanita* spp.	Voucher number	Location	*nuLSU*
	A. preissii (Fr.) Sacc.	PERTH 08690766	Kings Park, WA	KY290654
	A. preissii	PERTH 08774765	Kings Park, WA	KY290655
	A. preissii	PERTH 08774803	City of Melville, WA	KY290656
	A. pyramidiferina A.E.Wood	AD-C53054	SA	HQ539732
	A. quenda E.M.Davison	PERTH 08587116	City of Melville, WA	**OP235471**
	A. quenda	PERTH 09472754	City of Melville, WA	**OP235473**
	A. roseolifolia Y.Y.Cui, Q.Cai & Zhu L.Yang	HKAS101403	Hainan, China	NG_064593
	A. sp-AUS20	RET 474-3	City of Lithgow, NSW	ON817223
	A. sp-AUS20	RET 623-3	City of Lithgow, NSW	ON817224
	A. virgineoides Bas	HKAS77278	Hainan, China	MH486945
	A. yenii Zhu L.Yang & C.M.Chen	HKAS89016	Yunnan, China	MH486952
Strobiliformes	*A. strobiliformis* (Paulet ex Vittad.) Bertill.	MB-001177	Germany	MH486895
	A. cinereopannosa Bas	RET 318-8	Maine, USA	HQ539678
	A. aspericeps Y.Y.Cui, Q.Cai & Zhu L.Yang	HKAS 77783	Guangdong, China	MH486372
	A. cinereoradicata Y.Y.Cui, Q.Cai & Zhu L.Yang	HKAS63641	Yunnan, China	MH486452
Validae	*A. excelsa* (Fr.) Bertill.	HKAS96169	Austria	MH486492
	A. citrina Pers.	BW JLR 102106-1	New Jersey, USA	HQ539679
	A. flavoconia G.FAtk.	BW_PH22	Massachusetts, USA	HQ539693
	A. karea G.S. Ridl.	JAC13435	New Zealand	MT862273
	A. nothofagi G. Stev.	CS AK400	New Zealand	MT862267
Amanita	*A. subglobosa* Zhu L.Yang (outgroup)	HKAS58837	China	JN941152
	A. brunneola	PERTH 09472517	City of Melville, WA	**OP235469**
	A. brunneola	PERTH 09472614	City of Cockburn, WA	**OP235474**
	A. cretaceaverruca	PERTH 09479627	Shire of Manjimup, WA	**OP235470**
	A. cretaceaverruca	PERTH 09479716	City of Melville, WA	**OP235467**
	A. mallee	PERTH 09472797	Shire of Coolgardie, WA	**OP235468**
	A. validiuscula	PERTH 09480056	Shire of Cuballing, WA	**OP235472**

Table 2. Voucher information and GenBank accession numbers for some species from sect. Roanokenses. Newly published sequences are shown in bold. *ITS,* nuclear ribosomal transcribed-spacer region; *ef1-α*, translation elongation-factor 1-α region; *rpb2*, polymerase-II region; β-tubulin, β-tubulin region; WA, Western Australia; SA, South Australia.

Amanita spp.	Voucher number	Location	*ITS*	*ef1-α*	*rpb2*	β-tubulin
A. australis	PDD89861	New Zealand	GU222314			
A. australis	JAC12865	New Zealand	MT863756	MT977103	MT993772	MT993785
A. avellaneifolia	HKAS80011	Yunnan, China		MH508680	MH485872	MH485410

***Amanita* spp.**	**Voucher number**	**Location**	***ITS***	***ef1-α***	***rpb2***	**β-tubulin**
A. brunneola	PERTH 09472517	City of Melville, WA	**OP235497–500, OP235506**	**OP272679**	**OP272667**	**OP272663**
A. brunneola	PERTH 09472614	City of Cockburn, WA	**OP235501**	**OP272683**	**OP272666**	**OP272671**
A. carneiphylla	PERTH 08793530	City of Melville, WA		MN909832	MN928556	MN909829
A. carneiphylla	PERTH 08793565	Shire of Cuballing, WA		MN909833	MN928557	MN909830
A. carneiphylla	AD282179	Kangaroo Island, SA	**MN919212–16**	**MN909834**	**MN928558**	**MN909831**
A. cretaceaverruca	PERTH 09479627	Shire of Manjimup, WA	**OP235481–87, OP235507**	**OP272680**	**OP272668**	**OP272674**
A. cretaceaverruca	PERTH 09479716	City of Melville, WA	**OP235491–96**	**OP272677**		**OP272673**
A. elliptica	HKAS96797	Hainan, China		MH508765	MH485966	MH485490
A. gymnopus	HKAS89031	Yunnan, China		MH508852	MH486045	MH485563
A. hiltonii	PERTH 09004564	Shire of Mundaring, WA	MT365216–20	MT370480	MT370479	MT370482
A. kalamundae	PERTH 08616019	Shire of Murray, WA	JX398319			
A. kalamundae	PERTH 08615993	Shire of Manjimup, WA	KP898376–82			
A. mallee	PERTH 09472797	Shire of Coolgardie, WA	**OP235475–80, OP235490**	**OP272678**	**OP272665**	**OP272672**
A. manginiana	HKAS56933	China		KJ481943	KJ466603	KJ466515
A. miculifera	HKAS101425	Shenyang, China		MH508901	MH486093	MH485609
A. modesta	HKAS79688	China		KJ481944	KJ466604	KJ466516
A. neo-ovoidea	HKAS89025	Yunnan, China		MH508913	MH486106	MH485621
A. pareparina	JAC13371	New Zealand		MT977110	MT993779	MT993794
A. preissii	PERTH 08690766	Kings Park, WA		KY273109	KY288484	KY273105
A. quenda	PERTH 08587116	City of Melville, WA	NR151652	**OP272681**	**OP272669**	**OP272663**
A. quenda	PERTH 09472754	City of Melville, WA	**KP137058–62**		**OP272670**	**OP272676**
A. roseolifolia	HKAS101403	Hainan, China		MH509032	MH486219	MH485723
A. validiuscula	PERTH 09480056	Shire of Cuballing, WA	**OP235502–05, OP235508**	**OP272682**		**OP272675**
A. virgineoides	HKAS77278	Hainan, China		MH509166	MH486340	MH485846
A. yenii	HKAS89016	Yunnan, China		MH509172	MH486345	MH485851
A. djarilmari (outgroup)	PERTH 08776067	Shire of Cuballing, WA		MF000750	MF000755	MF000742

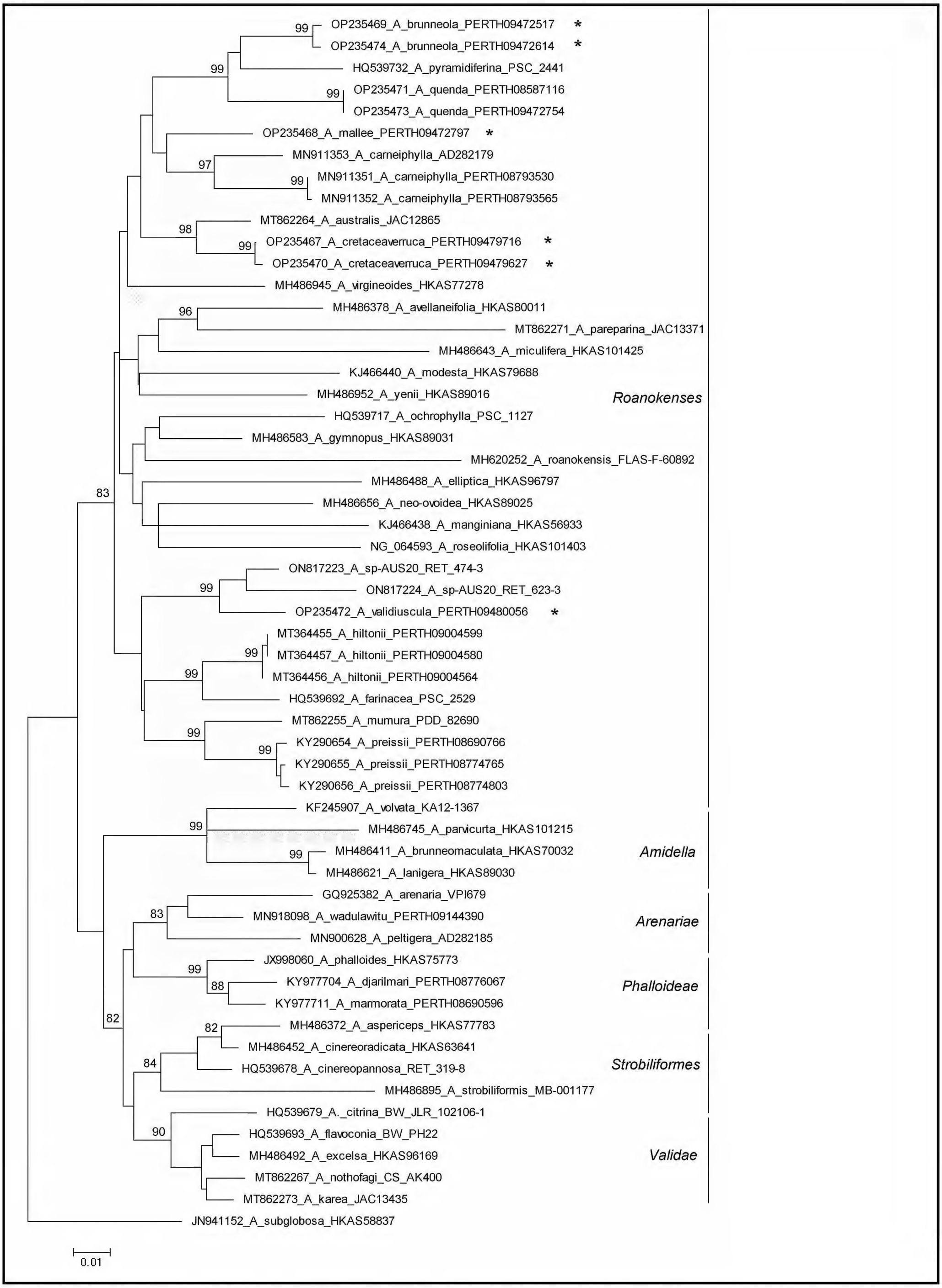
99
OP235469_A_brunneola_PERTH09472517 *
OP235474_A_brunneola_PERTH09472614 *
99
HQ539732_A_pyramidiferina_PSC_2441
99
OP235471_A_quenda_PERTH08587116
OP235473_A_quenda_PERTH09472754
OP235468_A_mallee_PERTH09472797 *
MN911353_A_carneiphylla_AD282179
97
99
MN911351_A_carneiphylla_PERTH08793530
MN911352_A_carneiphylla_PERTH08793565
MT862264_A_australis_JAC12865
98
99
OP235467_A_cretaceaverruca_PERTH09479716 *
OP235470_A_cretaceaverruca_PERTH09479627 *
MH486945_A_virgineoides_HKAS77278
96
MH486378_A_avellaneifolia_HKAS80011
MT862271_A_pareparina_JAC13371
MH486643_A_miculifera_HKAS101425
KJ466440_A_modesta_HKAS79688
MH486952_A_yenii_HKAS89016
Roanokenses
HQ539717_A_ochrophylla_PSC_1127
MH486583_A_gymnopus_HKAS89031
MH620252_A_roanokensis_FLAS-F-60892
MH486488_A_elliptica_HKAS96797
83
MH486656_A_neo-ovoidea_HKAS89025
KJ466438_A_manginiana_HKAS56933
NG_064593_A_roseolifolia_HKAS101403
ON817223_A_sp-AUS20_RET_474-3
99
ON817224_A_sp-AUS20_RET_623-3
OP235472_A_validiuscula_PERTH09480056 *
MT364455_A_hiltonii_PERTH09004599
99
MT364457_A_hiltonii_PERTH09004580
99
MT364456_A_hiltonii_PERTH09004564
HQ539692_A_farinacea_PSC_2529
MT862255_A_mumura_PDD_82690
99
99
KY290654_A_preissii_PERTH08690766
KY290655_A_preissii_PERTH08774765
KY290656_A_preissii_PERTH08774803
KF245907_A_volvata_KA12-1367
99
MH486745_A_parvicurta_HKAS101215
99
MH486411_A_brunneomaculata_HKAS70032
Amidella
MH486621_A_lanigera_HKAS89030
GQ925382_A_arenaria_VPI679
83
MN918098_A_wadulawitu_PERTH09144390
Arenariae
MN900628_A_peltigera_AD282185
JX998060_A_phalloides_HKAS75773
99
88
KY977704_A_djarilmari_PERTH08776067
Phalloideae
KY977711_A_marmorata_PERTH08690596
82
82
MH486372_A_aspericeps_HKAS77783
MH486452_A_cinereoradicata_HKAS63641
84
HQ539678_A_cinereopannosa_RET_319-8
Strobiliformes
MH486895_A_strobiliformis_MB-001177
HQ539679_A._citrina_BW_JLR_102106-1
90
HQ539693_A_flavoconia_BW_PH22
MH486492_A_excelsa_HKAS96169
Validae
MT862267_A_nothofagi_CS_AK400
MT862273_A_karea_JAC13435
JN941152_A_subglobosa_HKAS58837
0.01

Figure 1. Molecular phylogenetic analysis by the maximum-likelihood method of *nuLSU* (nuclear ribosomal large sub-unit rRNA region) sequences (809 base pair positions), showing the position of *Amanita brunneola, A. cretaceaverruca, A. mallee* and *A. validiuscula* within subgen. *Amanitina*. The tree is rooted with *A. subglobosa* (subgen. *Amanita* sect. *Amanita*). Each section is listed on the right the new species are indicated by *. Maximum-likelihood bootstrap values greater than 80% are shown on the branches.

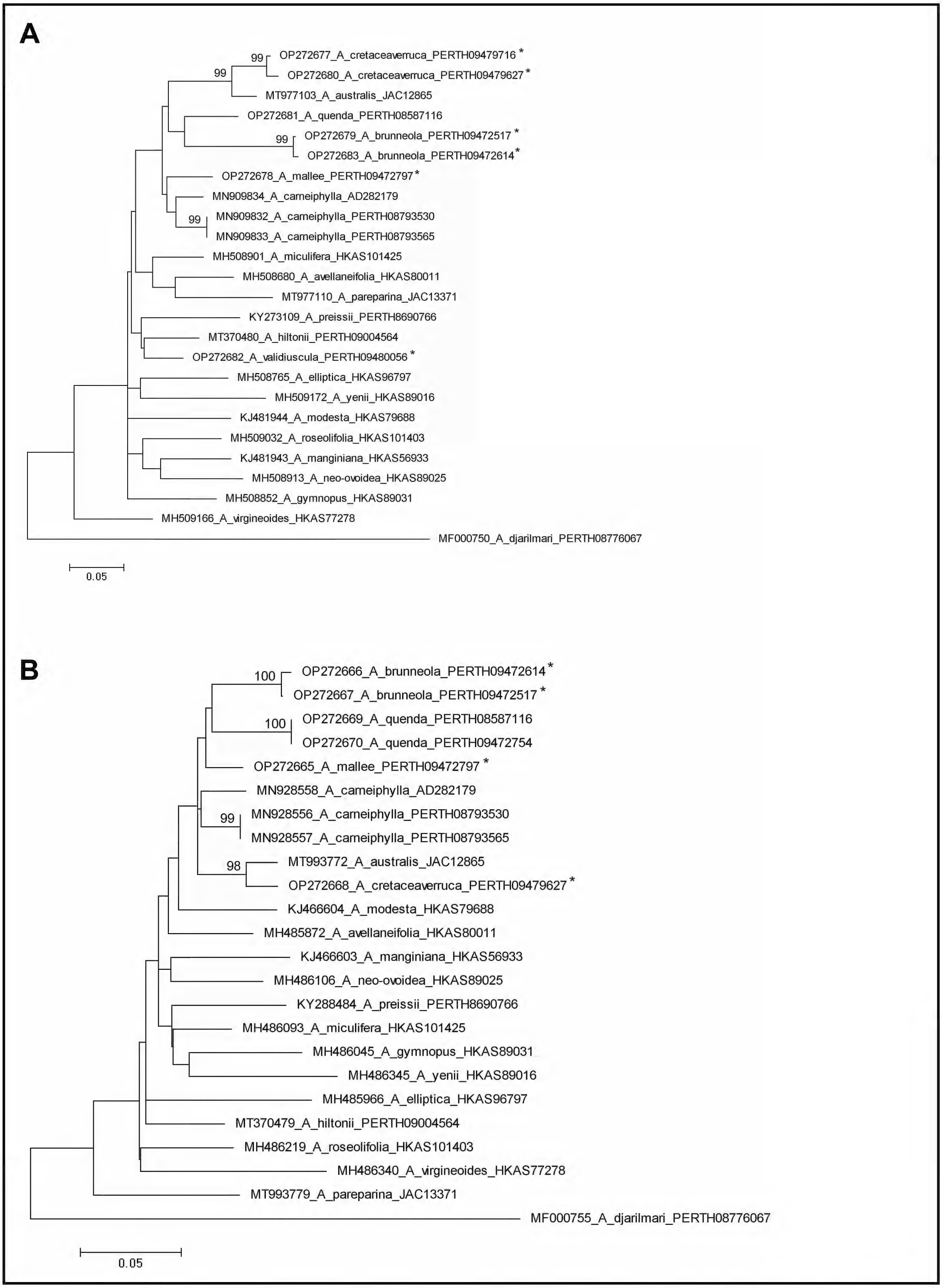
A
99
99
OP272677_A_cretaceaverruca_PERTH09479716 *
OP272680_A_cretaceaverruca_PERTH09479627 *
MT977103_A_australis_JAC12865
OP272681_A_quenda_PERTH08587116
99
OP272679_A_brunneola_PERTH09472517 *
OP272683_A_brunneola_PERTH09472614 *
OP272678_A_mallee_PERTH09472797 *
MN909834_A_carneiphylla_AD282179
99
MN909832_A_carneiphylla_PERTH08793530
MN909833_A_carneiphylla_PERTH08793565
MH508901_A_miculifera_HKAS101425
MH508680_A_avellaneifolia_HKAS80011
MT977110_A_pareparina_JAC13371
KY273109_A_preissii_PERTH8690766
MT370480_A_hiltonii_PERTH09004564
OP272682_A_validiuscula_PERTH09480056 *
MH508765_A_elliptica_HKAS96797
MH509172_A_yenii_HKAS89016
KJ481944_A_modesta_HKAS79688
MH509032_A_roseolifolia_HKAS101403
KJ481943_A_manginiana_HKAS56933
MH508913_A_neo-ovoidea_HKAS89025
MH508852_A_gymnopus_HKAS89031
MH509166_A_virgineoides_HKAS77278
MF000750_A_djarilmari_PERTH08776067
0.05
B
100
OP272666_A_brunneola_PERTH09472614 *
OP272667_A_brunneola_PERTH09472517 *
100
OP272669_A_quenda_PERTH08587116
OP272670_A_quenda_PERTH09472754
OP272665_A_mallee_PERTH09472797 *
MN928558_A_carneiphylla_AD282179
99
MN928556_A_carneiphylla_PERTH08793530
MN928557_A_carneiphylla_PERTH08793565
98
MT993772_A_australis_JAC12865
OP272668_A_cretaceaverruca_PERTH09479627 *
KJ466604_A_modesta_HKAS79688
MH485872_A_avellaneifolia_HKAS80011
KJ466603_A_manginiana_HKAS56933
MH486106_A_neo-ovoidea_HKAS89025
KY288484_A_preissii_PERTH8690766
MH486093_A_miculifera_HKAS101425
MH486045_A_gymnopus_HKAS89031
MH486345_A_yenii_HKAS89016
MH485966_A_elliptica_HKAS96797
MT370479_A_hiltonii_PERTH09004564
MH486219_A_roseolifolia_HKAS101403
MH486340_A_virgineoides_HKAS77278
MT993779_A_pareparina_JAC13371
MF000755_A_djarilmari_PERTH08776067
0.05

Figure 2. Molecular phylogenetic analysis by the maximum-likelihood method of the sequences 2A. *ef1-α* (translation elongation-factor 1-α (473 base pair positions). 2B. *rpb2* (RNA polymerase-II region) sequences (639 base pair positions). 2C. β-tubulin (β-tubulin region) sequences (218 base pair positions). 2D. Concatenated *nuLSU, rpb2, ef1-α* and β-tubulin sequences (2115 base pair positions) of species in sect. *Roanokenses*. All trees are rooted with *Amanita djarilmari* (sect. *Phalloideae*). The new species are indicated by *. Maximum-likelihood bootstrap values greater than 80% are shown on the branches.

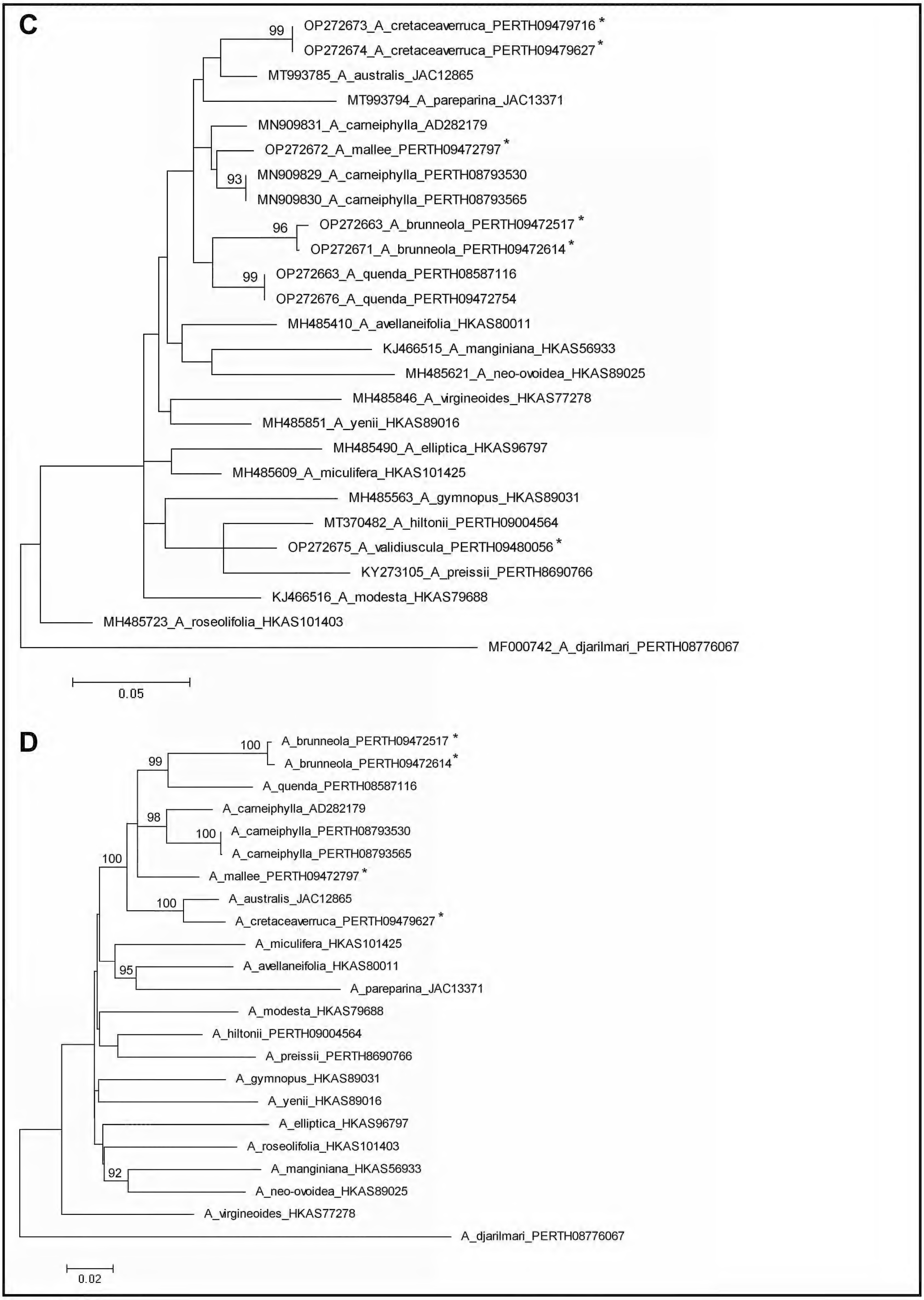
C
99
OP272673_A_cretaceaverruca_PERTH09479716 *
OP272674_A_cretaceaverruca_PERTH09479627 *
MT993785_A_australis_JAC12865
MT993794_A_pareparina_JAC13371
MN909831_A_carneiphylla_AD282179
OP272672_A_mallee_PERTH09472797 *
93
MN909829_A_carneiphylla_PERTH08793530
MN909830_A_carneiphylla_PERTH08793565
96
OP272663_A_brunneola_PERTH09472517 *
OP272671_A_brunneola_PERTH09472614 *
99
OP272663_A_quenda_PERTH08587116
OP272676_A_quenda_PERTH09472754
MH485410_A_avellaneifolia_HKAS80011
KJ466515_A_manginiana_HKAS56933
MH485621_A_neo-ovoidea_HKAS89025
MH485846_A_virgineoides_HKAS77278
MH485851_A_yenii_HKAS89016
MH485490_A_elliptica_HKAS96797
MH485609_A_miculifera_HKAS101425
MH485563_A_gymnopus_HKAS89031
MT370482_A_hiltonii_PERTH09004564
OP272675_A_validiuscula_PERTH09480056 *
KY273105_A_preissii_PERTH8690766
KJ466516_A_modesta_HKAS79688
MH485723_A_roseolifolia_HKAS101403
MF000742_A_djarilmari_PERTH08776067
0.05
D
100
A_brunneola_PERTH09472517 *
A_brunneola_PERTH09472614 *
99
A_quenda_PERTH08587116
A_carneiphylla_AD282179
98
100
A_carneiphylla_PERTH08793530
A_carneiphylla_PERTH08793565
100
A_mallee_PERTH09472797 *
100
A_australis_JAC12865
A_cretaceaverruca_PERTH09479627 *
A_miculifera_HKAS101425
95
A_avellaneifolia_HKAS80011
A_pareparina_JAC13371
A_modesta_HKAS79688
A_hiltonii_PERTH09004564
A_preissii_PERTH8690766
A_gymnopus_HKAS89031
A_yenii_HKAS89016
A_elliptica_HKAS96797
A_roseolifolia_HKAS101403
92
A_manginiana_HKAS56933
A_neo-ovoidea_HKAS89025
A_virgineoides_HKAS77278
A_djarilmari_PERTH08776067
0.02

Figure 2. cont.

Taxonomy

Amanita brunneola E.M.Davison & Giustiniano, *sp. nov.*

Type: Wireless Hill Park, City of Melville, Western Australia [precise locality withheld for conservation reasons], 14 June 2020, *E.M. & P.J.N. Davison* EMD 22-2020 (*holo*: PERTH 09472517). [MB845575].

Pileus 20–64 mm wide, up to 5 mm thick, convex becoming plane with a decurved margin, depressed with age, ivory white (B) cream (D) to buff to clay buff to milky coffee (3A3–4A2–3–5B2–D4) with pale margin, surface tacky when moist, margin non-striate, slightly appendiculate. *Universal veil on pileus* adnate, thin, submembranous, crustose breaking into patches or small floccose warts in centre of disc, white or ivory white (B) or cream (D) or pale vinaceous buff (5B2). *Lamellae* adnate to adnexed, subcrowded to close, white ageing cream (4A2), 3–8 mm broad, margin concolorous, fimbriate; lamellulae scarce to plentiful, in several lengths, truncate or rounded truncate or subattenuate or attenuate. *Stipe* 30–71 × 4–10 mm, cylindric, white, surface smooth. *Partial veil* superior or apical, descendant, flaring, striate above, membranous, persistent, white. *Bulb* 10–17 × 11–20 mm globose or globose with pointed base, white to buff to brown to grey. *Remains of universal veil at top of bulb* not apparent or a rim or small ridges or a free limb up to 2 mm high, white. *Pileus and stipe context* white, unchanging, stipe solid. *Smell* none. *Spore deposit* white. (Figure 3)

Basidiospores [280/14/10] (9–)10.5–15(–18) × (4–)4.5–5.5(–6) µm, (**L** = 11.5–15.5 µm; **L'** = 12.5 µm, **W** = 4.5–5.2 µm; **W'** = 5.0 µm; Q = (1.83–)2.10–3.00(–3.40); **Q** = 2.35–2.98; **Q'** = 2.51), hyaline, colourless, thin-walled, smooth, amyloid, cylindric, contents monoguttulate, apiculus sublateral, cylindric or tapered, *c.* 1 × 1.5 µm, truncate or rounded. *Pileipellis* up to 200 µm thick with a colourless gelatinised suprapellis up to 100 µm thick and a colourless or pale brown subpellis, consisting of filamentous hyphae and very infrequent vascular hyphae (inflated cells not observed), filamentous hyphae 3–15 µm wide, radially orientated with some interweaving, thick-walled, colourless, gelatinising; vascular hyphae 2–3 µm wide, colourless; clamp connections not observed. *Pileus context* consisting of filamentous hyphae (dominant or equal), inflated cells and very infrequent vascular hyphae, filamentous hyphae 3–50 µm wide with widest constricted at septa, thin-walled, colourless; inflated cells to 150 × 50 µm, thin-walled, clavate or ellipsoid or ventricose or cylindric, terminal, colourless; vascular hyphae 3–10 µm wide, occasionally branched, pale yellow; clamp connections not observed. *Lamella trama* bilateral, divergent. *Central stratum* up to 40 µm wide, consisting of filamentous hyphae (inflated cells and vascular hyphae not observed), filamentous hyphae 3–18 µm wide with widest constricted at septa, thin walled, colourless, axially orientated; clamp connections very infrequent. *Subhymenial base* with angle of divergence *c.* 15–30° from central stratum, with filamentous hyphae following a smooth curve to subhymenium, consisting of dominant filamentous hyphae, inflated cells and very infrequent to frequent vascular hyphae; filamentous hyphae 3–22 µm wide, widest close to subhymenium and constricted at septa, frequently branched, thin-walled, colourless; inflated cells up to 95 × 35 µm thin-walled, clavate or ventricose or ellipsoid or ovoid or pyriform, colourless; vascular hyphae 2–5 µm wide, occasionally branched, pale yellow; clamp connections frequent. *Subhymenium* initially ramose becoming coralloid to inflated ramose, with basidia arising terminally from narrow hyphae or barely inflated hyphal segments 4–15 µm wide; clamp connections frequent. *Lamella edge tissue* sterile, with inflated cells frequent to abundant, up to 25 × 10 µm when clavate or up to 35 × 20 µm when pyriform or up to 25 × 18 µm when ovoid, colourless, some disarticulating. *Basidia* [200/10/10] (27–)38–54(–58) × (9–)10–13(–14) µm, thin-walled, colourless, *c.* 98% 4-spored, *c.* 0.5% 3-spored, *c.* 1.5% 2-spored, sterigmata to 7 × 2 µm, clamp connections frequent, proliferating. *Universal veil on pileus* not layered, elements with no dominant orientation, consisting of frequent filamentous hyphae, dominant inflated cells and very infrequent vascular hyphae, filamentous hyphae 4–20 µm wide with widest constricted at septa, colourless, gelatinising; inflated cells up to 90 × 30 µm when pyriform or up to 70 × 70 µm when spherical or up to 100 × 50 µm when ovoid or up to 100 × 35 µm when clavate, terminal or occasionally in chains of up to 3, colourless, gelatinising; vascular hyphae 3–5 µm wide, colourless; clamp connections very infrequent. *Universal veil on stipe base* not layered, elements with somewhat axial orientation, consisting of dominant to frequent filamentous hyphae, frequent to dominant inflated cells and very infrequent to frequent vascular hyphae, filamentous hyphae 2–15 µm wide, colourless or pale yellow, gelatinising; inflated cells up to 60 × 60 µm when spherical or up to 110 × 55 µm when pyriform or up to 50 × 40 µm when ellipsoidal or up to 120 × 60 µm when ovoid or up to 150 × 50 µm when clavate, terminal, colourless or pale yellow, gelatinising; vascular hyphae 3–15 µm wide, occasionally branched, pale yellow or colourless; clamp connections not observed. *Stipe context* longitudinally acrophysalidic, consisting of frequent filamentous hyphae, dominant acrophysalides and frequent to infrequent vascular hyphae, filamentous hyphae 2–10 µm wide, colourless or pale yellow, gelatinising; acrophysalides to 300 × 40 µm, clavate, terminal, colourless or pale yellow, gelatinising; vascular hyphae 3–20 µm wide, occasionally branched, pale yellow or pale yellowish-brown; clamp connections very infrequent. *Partial veil* elements with a radial orientation, consisting of frequent filamentous hyphae, equal to dominant inflated cells and infrequent vascular hyphae, filamentous hyphae 2–8 µm wide, colourless, gelatinising; inflated cells up to 50 × 27 µm when pyriform or up to 60 × 20 µm when clavate or up to 40 × 25 µm when ovoid or up to 25 × 25 µm when spherical, colourless, gelatinising; vascular hyphae 2–8 µm wide, pale yellow or colourless; clamp connections very infrequent. (Figure 4)

Diagnostic features. Basidiomata small to medium. Pileus ivory white becoming cream to buff to clay buff to milky coffee, paler at margin., margin appendiculate when young. Universal veil on pileus white, thin, as patch or small slightly floccose warts mainly in centre of disc. Lamellae white. Stipe white. Partial veil superior, white, descendant, flaring, membranous. Universal veil at stipe base a narrow white rim at the top of the globose basal bulb. Spores amyloid, cylindric. Universal veil on pileus of dominant inflated cells and filamentous hyphae. Clamp connections present, most frequent in lamellae.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 25 Apr. 1990, *E.M. & P.J.N. Davison* EMD 16/90 (PERTH 03097056); 24 May 1992, *E.M. & P.J.N. Davison* EMD 25/92 (PERTH 03096823); 16 June 1992, *E.M. & P.J.N. Davison* EMD 57-1992 (PERTH 09472355); 11 May 2008, *E.M. & P.J.N. Davison* EMD 4-2008 (PERTH 09472746); 30 May 2010, *E.M. & P.J.N. Davison* EMD 6-2010 (PERTH 09472614); 8 June 2016, *E.M. Davison & P.J.N. Davison* EMD 47-2016 (PERTH 09479678); 14 June 2020, *E.M. & P.J.N. Davison* EMD 20-2020 (PERTH 09472681); 14 June 2020, *E.M. & P.J.N. Davison* EMD 21-2020 (PERTH 09472649); 14 June 2020, *E.M. & P.J.N. Davison* EMD 23-2020 (PERTH 09472606); 16 June 1989, *O.K. Miller Jr & H. Miller* E 661 (PERTH 07547722).

Phenology. Fruiting period is April to June.

Distribution and habitat. Singly or gregarious in sandy soil. In degraded native vegetation, nearby plants include *Allocasuarina fraseriana, Corymbia calophylla* and *Eucalyptus marginata*. Occurs on the Swan Coastal Plain Perth SWA02 IBRA subregion (Department of the Environment 2013).

Conservation status. To be listed as Priority Two (poorly known species) under Conservation Codes for Western Australian Flora (Tanya Llorens pers. comm.).

Etymology. The epithet is from the Latin *brunneolus*, referring to the brownish colour of the pileus.

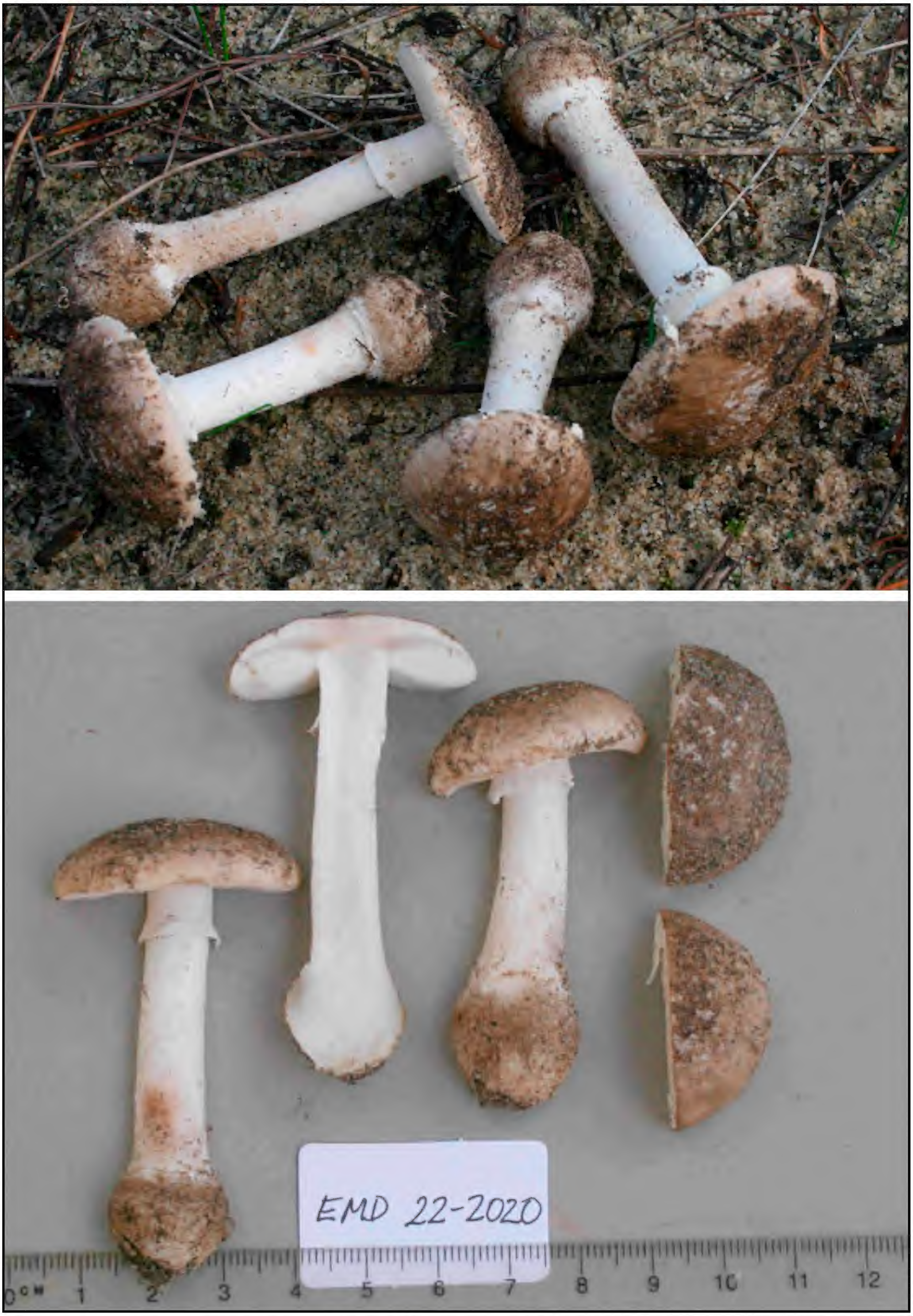

Figure 3. *Amanita brunneola* basidiomes, *E.M. & P.J.N. Davison* EMD 22-2020 (*holo*: PERTH 09472517). Photographs E.M. Davison.

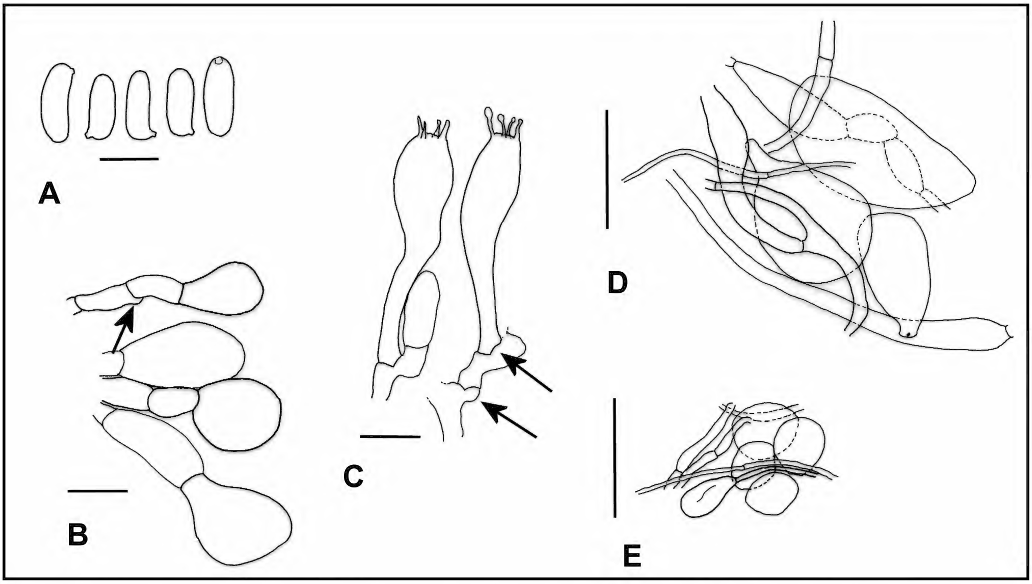

Figure 4. *Amanita brunneola*. A – spores from spore print; B – marginal cells; C – basidia; D – universal veil on pileus, gently squashed; E – universal veil at stipe base, gently squashed. Scale bars = 10 µm (A–C); 50 µm (D, E); clamp connections indicated by arrows. Images from *E.M. & P.N.J. Davison* EMD 22-2020 (*holo*: PERTH 09472517).

Notes. *Amanita brunneola* consistently clusters close to *A. pyramidiferina* and *A. quenda* in our molecular analyses (Figures 1, 2). A comparison of cloned haplotypes of the *ITS* region from *A. brunneola* and *A. quenda* (no *ITS* sequences of *A. pyramidiferina* are available) shows there is considerable variation between the clones; they differ by 0.3–3.3% within an individual, and 1.1–2.9% between collections of the same species (Table 3). Clones of these two species differ by 28.4–29.7%, well beyond the observed infraspecific variation.

Several small to medium species with a white or pale brown pileus and cylindrical spores have been described from Australia. *Amanita brunneola* is similar to *A. angustispora* Cleland, a poorly known species from Encounter Bay in South Australia (Cleland 1927). Both species are of similar size and colour, both have a white dependent partial veil, and globose bulb; however, Cleland (1927) mentions that the volva is sheathing, ample and whitish in *A. angustispora*, whilst in *A. brunneola* it is either not apparent, or forms small ridges or a free limb to 2 mm high. This is an important difference. Both species have clamp connections. However, there is considerable confusion about the identity of *A. angustispora* which has been detailed by Reid (1980) and Tulloss (http://www.amanitaceae.org/?Amanita%20angustispora [accessed 7 June 2022]). The uncertainty could be resolved if usable DNA is obtained from the Cleland collections of *A. angustispora.*

Amanita clelandii (E.-J.Gilbert) E.-J.Gilbert is another small, white species with cylindric spores collected by Cleland from Encounter Bay and Kinchina in South Australia. Reid (1980) records the spores as being 9.0–16.0 × 4.5–6.0 µm, similar to those of *A. brunneola*, however, clamp connections were not reported in these collections (Reid 1980). This is an important morphological difference (Bas 1969).

On the basis of the absence of a sheathing volva which distinguishes *A. brunneola* from *A. angustispora*, and the presence of clamp connections which distinguishes it from *A. clelandii*, *A. brunneola* is described as a new species.

Table 3. Percentage difference between *ITS* clones from *A. brunneola* and *A. quenda.* The *ITS* region is 600–668 base pairs long.

Name	**No. of clones**	***A. brunneola***		***A. quenda***	
		PERTH 09472614	**PERTH 09472517**	**PERTH 08587116**	**PERTH 09472754**
A. brunneola					
PERTH 09472614, OP235501	1				
PERTH 09472517, OP235497–500, OP235506	5	1.7–2.5	0.3–2.2		
A. quenda					
PERTH 08587116, NR_151652	1	29.0	28.6–29.2		
PERTH 09472754, KP137058–62	5	28.8–29.5	28.4–29.7	1.1–2.9	0.3–3.3

Amanita cretaceaverruca E.M.Davison & Giustiniano, *sp. nov.*

Type: Perup, Shire of Manjimup, Western Australia [precise locality withheld for conservation reasons], 2 June 2013, *E.M. Davison & P.J.N. Davison* EMD 30-2013 (*holo*: PERTH 09479627). [MB845576].

Pileus 26–51 mm wide, up to 5 mm thick, convex becoming plane with a decurved margin, depressed with age, buff to clay buff to fawn (4A3–6C4–E5, pale yellow to brownish orange to brown) with pale margin, surface tacky when moist, margin non-striate, slightly appendiculate. *Universal veil on pileus* easily removed, thick, felted, crustose breaking into patches or straight sided warts in centre of disc, white to ivory white (B) to clay buff to fawn (6C4) with age. *Lamellae* free to adnexed to adnate, subcrowded to close, white ageing ivory white (B) to pale clay buff, 4–5 mm broad, margin concolorous, fimbriate; lamellulae plentiful, in several lengths, shortest truncate longest subattenuate or attenuate. *Stipe* 40–70 × 6–9 mm, cylindric or tapering upwards, white or ivory white, surface floccose below partial veil. *Partial veil* superior, descendant, flaring, striate above, membranous, persistent, white. *Bulb* 12–22 × 15–28 mm globose or ovoid or turbinate, white. *Remains of universal veil at top of bulb* not apparent or small rim, white. *Pileus and stipe context* white or ivory white, unchanging, stipe centre watersoaked. *Smell* none. *Spore deposit* white. (Figure 5)

Basidiospores [140/7/2] (8–)9–13(–14) × (5–)6–7.5(–8) µm, (**L** = 9.7–12.2 µm; **L'** = 11.5 µm, **W** = 6.2–7.0 µm; **W'** = 6.6 µm; Q = (1.33–)1.47–2.00(–2.18); **Q** = 1.57–1.84; **Q'** = 1.74), hyaline, colourless, thin-walled, smooth, amyloid, ellipsoid to elongate, contents monoguttulate and granular, apiculus sublateral, tapered or cylindric, *c.* 1 × 1 µm, truncate or rounded. *Pileipellis* up to 150 µm thick with a colourless gelatinised suprapellis up to 100 µm thick and pale yellow or pale brown subpellis, consisting of filamentous hyphae and frequent to very infrequent vascular hyphae (inflated cells not observed), filamentous hyphae 3–7 µm wide, radially orientated with some interweaving, thick-walled, colourless, gelatinising; vascular hyphae 2–10 µm wide, occasionally branched, pale yellow to brownish yellow. *Pileus context* consisting of dominant filamentous hyphae, inflated cells and frequent to infrequent vascular hyphae, filamentous hyphae 3–35 µm wide with widest constricted at septa, thin-walled, colourless; inflated cells to 190 × 50 µm, thin-walled, clavate or ventricose or ellipsoid or ovoid or cylindric, terminal, colourless; vascular hyphae 3–7 µm wide, occasionally branched, very pale yellow or brownish yellow. *Lamella trama* bilateral, divergent. *Central stratum* consisting of filamentous hyphae and infrequent vascular hyphae (inflated cells not observed), filamentous hyphae 2–12 µm wide with widest constricted at septa, thin walled, colourless, axially orientated; vascular hyphae 3–4 µm wide, pale yellow. *Subhymenial base* with angle of divergence *c.* 10–15° from central stratum, with filamentous hyphae following a smooth curve to subhymenium, consisting of dominant filamentous hyphae, inflated cells and infrequent vascular hyphae; filamentous hyphae 2–20 µm wide, widest close to subhymenium and constricted at septa, frequently branched, thin-walled, colourless; inflated cells up to 50 × 20 µm, thin-walled, clavate, colourless; vascular hyphae 2–6 µm wide, occasionally branched, colourless or pale yellow. *Subhymenium* initially ramose becoming inflated apically, with basidia arising terminally from narrow hyphae or barely inflated hyphal segments 6–23 µm wide. *Lamella edge tissue* sterile, with inflated cells frequent, up to 25 × 20 µm when ovoid or up to 25 × 25 µm when pyriform or up to 18 × 18 µm when spherical, colourless, some disarticulating. *Basidia* [40/2/2] (29–)32–52(–53) × (10–)11–12(–13) µm, thin-walled, colourless, *c.* 85% 4-spored, *c.* 15% 3-spored, sterigmata to 5 × 2 µm. *Universal veil on pileus* not layered, elements with somewhat upright orientation, consisting of frequent filamentous hyphae, dominant inflated cells and very infrequent vascular hyphae, filamentous hyphae 3–10 µm wide, colourless, gelatinising; inflated cells up to 40 × 40 µm when spherical or up to 70 × 55 µm when ovoid or up to 35 × 25 µm when pyriform or up to 80 × 20 µm when clavate or up to 110 × 20 µm when cylindric, terminal or in chains of up to 4, colourless or very pale brown, gelatinising; vascular hyphae 3–5 µm wide, occasionally branched, colourless or pale yellow. *Universal veil on stipe base* not layered, elements with somewhat axial or no dominant orientation, consisting of equal to frequent filamentous hyphae, inflated cells and very infrequent vascular hyphae, filamentous hyphae 3–17 µm wide, colourless, gelatinising; inflated cells up to 80 × 80 µm when spherical or up to 45 × 35 µm when pyriform or up to 50 × 35 µm when ovoid or up to 70 × 55 µm when ellipsoid, terminal, colourless, gelatinising; vascular hyphae 2 µm wide, pale yellow. *Stipe context* longitudinally acrophysalidic, consisting of frequent filamentous hyphae, dominant acrophysalides and frequent to infrequent vascular hyphae, filamentous hyphae 2–10 µm wide, colourless; acrophysalides to 250 × 35 µm, clavate or cylindric, terminal, colourless, gelatinising; vascular hyphae 2–12 µm wide, occasionally branched, pale brownish-yellow. *Partial veil* elements with a radial orientation, consisting of frequent filamentous hyphae, dominant inflated cells and very infrequent vascular hyphae, filamentous hyphae 2–12 µm wide with widest constricted at septa, colourless, gelatinising; inflated cells up to 30 × 20 µm when ovoid or up to 80 × 20 µm when clavate or up to 40 × 20 µm when pyriform or up to 160 × 25 µm when cylindric, colourless, gelatinising; vascular hyphae 3–5 µm wide, occasionally branched, pale yellow. Clamp connections not observed in any tissue. (Figure 6)

Diagnostic features. Basidiomata very small to medium. Pileus buff to clay buff to fawn paler at margin, margin appendiculate when young. Universal veil on pileus white, thick, as patch or straight sided warts mainly in centre of disc. Lamellae white. Stipe white. Partial veil superior, white, descendant, flaring, membranous. Universal veil at stipe base not apparent or a narrow white rim at the top of the globose or ovoid basal bulb. Spores amyloid, ellipsoid to elongate. Universal veil on pileus of dominant inflated cells and filamentous hyphae. Clamp connections not seen.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 3 June 2011, *E.M. & P.J.N. Davison* EMD 21-2011 (PERTH 09479716).

Phenology. Fruiting period is June.

Distribution and habitat. Gregarious in sandy clay or peaty soil. In native vegetation, nearby plants include *Gastrolobium biloba, Melaleuca preissii, Eucalyptus grandis* and *E. rudis*. Occurs on the Swan Coastal Plain Perth SWA02 and Southern Jarrah Forest JAF02 IBRA subregions (Department of the Environment 2013).

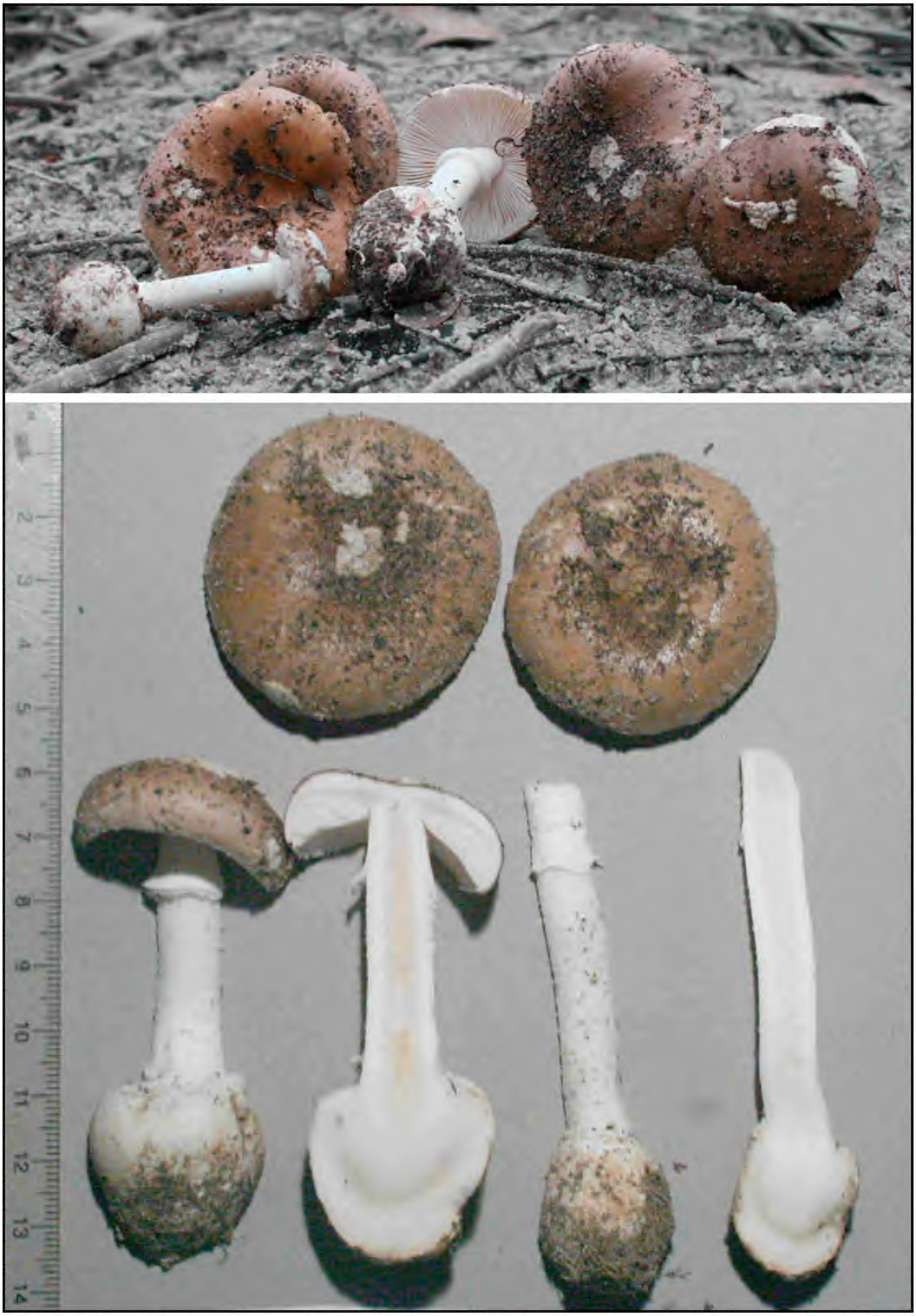

Figure 5. *Amanita cretaceaverruca* basidiomes, *E.M. Davison & P.J.N. Davison* EMD 30-2013 (*holo*: PERTH 09479627). Photographs E.M. Davison.

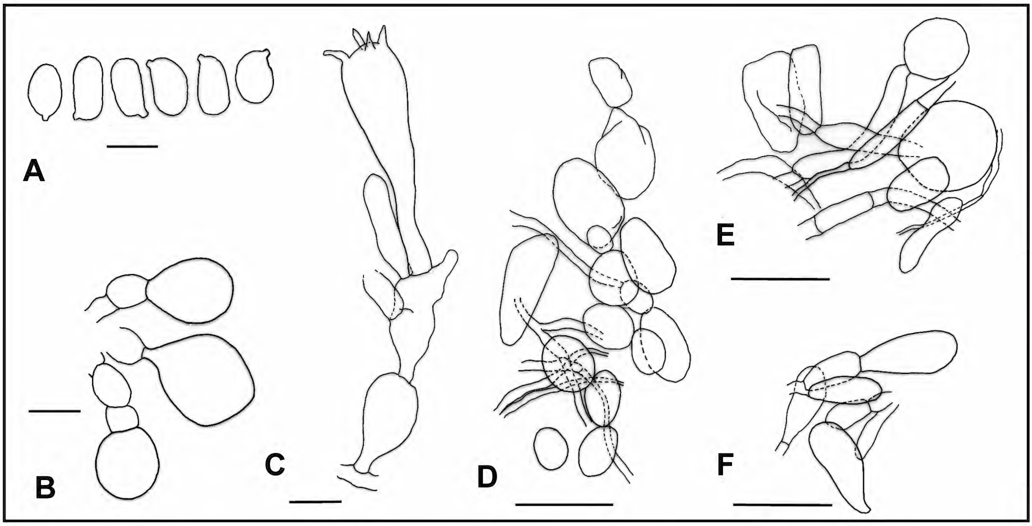

Figure 6. *Amanita cretaceaverruca*. A – spores from spore print; B – marginal cells; C – basidia; D –section through universal veil in centre of pileus; E – universal veil at stipe base, gently squashed; F – partial veil margin, unsquashed. Scale bars = 10 µm (A–C); 50 µm (D–F). Images from *E.M. Davison & P.J.N. Davison* EMD 30-2013 (*holo*: PERTH 09479627).

Conservation status. To be listed as Priority Two (poorly known species) under Conservation Codes for Western Australian Flora (Tanya Llorens pers. comm.).

Etymology. The epithet is from the Latin *cretaceous* and *verruca* referring to the thick white warts on the pileus.

Notes. *Amanita cretaceaverruca* clusters with the New Zealand species *A. australis* (Figures 1, 2). A comparison of cloned haplotypes of the *ITS* region from *A. cretaceaverruca* shows there is considerable variation between these clones; they differ by 0.3–5.6% within an individual, and 1.3–5.9% between collections of the same species (Table 4). The two sequences of *A. australis* differ by 32.1% indicating that one may have been mis-identified. Sequences from *A. cretaceaverruca* differ from MT863756 by 15.1–17.0%, and from GU222314 by 31.2–32.9%, indicating they are not the same.

Published descriptions of Australian amanitas include two small to medium species with a brown pileus, inapparent remains of the universal veil at the top of the globose to ovoid bulb, and elongate amyloid spores. *Amanita subalbida* Cleland has a pallid brownish to nearly white pileus with mealy or thin pulverulent to sub-felted universal veil (Cleland 1931; Bas 1969), not a thick felted, crustose universal veil which breaks into white warts. Also, *A. subalbida* has infrequent clamp connections (Bas 1969, Reid 1980), whilst these have not been seen in *A. cretaceaverruca*.

Amanita cretaceaverruca is superficially similar to *A. kalamundae* O.K.Mill. They have similar shaped spores (*A. cretaceaverruca* **Q** = 1.57–1.84, *A. kalamundae* **Q** = 1.44–1.87 (Miller 1991; McGurk *et al.* 2016), however, in *A. kalamundae* the partial veil, warts on the pileus, bulb and context yellow with age or with handling. Also, clamp connections are present, although infrequent in *A. kalamundae*. Cloned haplotypes of the *ITS* region are available for both *A. cretaceaverruca* and *A. kalamundae*. As can be seen from Table 4, there is considerable variation between clones: they differ by 0.3–5.6% within an individual, by up to 7.3% among collections of the same species, but by more than 30% between these two species, well beyond the observed infraspecific variation. On this basis, *A. cretaceaverruca* is described as a new species.

Table 4. Percentage difference between *ITS* clones from *A. cretaceaverruca* and *A. kalamundae*, and sequences of *A. australis.* The *ITS* region is 571–608 base pairs long.

Collection	No. of clones	*A. cretaceaverruca*		*A. australis*		*A. kalamundae*	
		PERTH 09479627	PERTH 09479716	PDD89861	JAC12865	PERTH 08616019	PERTH 08615993
A. cretaceaverruca							
PERTH 09479627, OP235481–87, OP235507	8	0.3–5.6					
PERTH 09479716, OP235491–96	6	1.3–5.9	0.5–3.3				
A. australis							
PDD89861, GU222314		31.6–32.9	31.2–32.7				
JAC12865, MT863756		15.2–17.0	15.1–16.3	32.1			
A. kalamundae							
PERTH 08616019, JX398319	1	35.7–37.4	36.0–37.0	39.1	38.2		
PERTH 08615993, KP898376–82	7	34.3–36.7	34.4–36.1	38.0–38.5	36.5–37.5	4.4–7.3	0.8–4.8

Amanita mallee E.M.Davison, Giustiniano & M.D.Barrett, *sp. nov.*

Type: Shire of Coolgardie, Western Australia [precise locality withheld for conservation reasons], 13 December 2012, *M.D. Barrett* F48/12 (*holo*: PERTH 09472797). [MB845577].

Pileus 70–83 mm wide, up to 22 mm thick, plane, margin non-striate, not appendiculate, white. *Universal veil on pileus* adnate, thin patches, white. *Lamellae* adnexed, subcrowded, white with cream tint, margin paler, fimbriate; lamellulae frequent, in several lengths, attenuate. *Stipe* 40–50 mm long, 14–18 mm wide, cylindric or narrowing downwards, white, surface smooth. *Partial veil* central, descendant, membranous, breaking up, striate above, white. *Bulb* 40–55 × 17–20 mm ovoid to carrot shaped, encrusted with sand. *Remains of universal veil at top of bulb* a thin membranous free limb to 5 mm high, white. *Pileus and stipe context* white, unchanging, stipe solid. *Smell* none. (Figure 7)

Basidiospores [100/5/1] (10–)10.5–13.5(–14) × (4.5–)5–6(–7) µm, (**L** = 12.0–12.8 µm; **L’** = 12.2 µm, **W** = 5.4–5.9 µm; **W’** = 5.6 µm; Q = (1.83–)2.00–2.60(–3.00); **Q** = 2.09–2.26; **Q’** = 2.19), hyaline, colourless, thin-walled, smooth, amyloid, cylindric, contents monoguttulate, apiculus sublateral, cylindric, *c.* 1 × 1 µm, truncate. *Pileipellis* up to 200 µm thick with colourless gelatinised suprapellis up to 50 µm thick and colourless subpellis, consisting of filamentous hyphae and infrequent vascular hyphae (inflated cells not observed), filamentous hyphae 5–7 µm wide, thick-walled, walls hyaline, gelatinising, contents colourless, radially orientated with some interweaving; vascular hyphae 3–6 µm wide, colourless; clamp connections not observed. *Pileus context* consisting of dominant filamentous hyphae, frequent inflated cells and frequent vascular hyphae, filamentous hyphae 3–50 µm wide with widest constricted at septa, thin-walled, colourless; inflated cells to 350 × 40 µm, thin-walled, ventricose, terminal, colourless; vascular hyphae 10–12 µm wide, occasionally branched, very pale yellow; clamp connections present. *Lamella trama* bilateral, divergent. *Central stratum* consisting of filamentous hyphae (inflated cells and vascular hyphae not observed), filamentous hyphae 2–15 µm wide with widest constricted at septa, thin walled, colourless, axially orientated; clamp connections present. *Subhymenial base* with angle of divergence *c.* 20° from central stratum, with filamentous hyphae following a smooth curve to subhymenium, consisting of dominant filamentous hyphae, inflated cells and infrequent vascular hyphae; filamentous hyphae 5–30 µm wide, widest close to subhymenium and constricted at septa, frequently branched, thin-walled, colourless; inflated cells up to 150 × 40 µm, thin-walled, cylindric or ventricose or clavate, colourless; vascular hyphae 2–6 µm wide, occasionally branched, very pale yellow; clamp connections frequent. *Subhymenium* ramose, with basidia arising terminally from narrow hyphae or barely inflated hyphal segments 5–10 µm wide; clamp connections present. *Lamella edge tissue* sterile, with inflated cells abundant, up to 45 × 22 µm when pyriform or up to 25 × 25 µm when spherical or up to 30 × 25 µm when ovoid, colourless, some disarticulating. *Basidia* [20/1/1] (41–)43–56 × 10–12 µm, thin-walled, colourless, *c.* 95% 4-spored, *c.* 5% 3-spored, sterigmata to 6 × 2 µm, clamp connections frequent. *Universal veil on pileus* not layered, elements with no dominant orientation, consisting of frequent filamentous hyphae and dominant inflated cells (vascular hyphae not observed), filamentous hyphae 3–12 µm wide, colourless, gelatinising; inflated cells up to 90 × 60 µm when ellipsoid or up to 60 × 60 µm when spherical or up to 85 × 55 µm when ovoid, terminal, colourless, gelatinising; clamp connections frequent. *Universal veil on stipe base* not layered, elements with somewhat axial orientation, consisting of dominant filamentous hyphae, infrequent inflated cells and infrequent vascular hyphae, filamentous hyphae 4–10 µm wide, colourless, many collapsed; inflated cells up to 75 × 20 µm when clavate or up to 175 × 35 µm when ventricose, terminal, colourless; vascular hyphae 5–6 µm wide, pale yellow; clamp connections infrequent. *Stipe context* longitudinally acrophysalidic, consisting of frequent filamentous hyphae, dominant acrophysalides and infrequent vascular hyphae, filamentous hyphae 3–8 µm wide, colourless; acrophysalides to 310 × 30 µm, clavate, terminal, colourless gelatinising; vascular hyphae 10–13 µm wide, occasionally branched, pale yellow; clamp connections infrequent. *Partial veil* elements with a radial orientation, consisting of dominant filamentous hyphae, frequent inflated cells and infrequent vascular hyphae, filamentous hyphae 2–9 µm wide, colourless, collapsing; inflated cells up to 175 × 35 µm when clavate or up to 230 × 30 µm when ventricose, colourless; vascular hyphae 2–8 µm wide, occasionally branched, very pale yellow; clamp connections infrequent. (Figure 8)

Diagnostic features. Basidiomata medium. Pileus white with thin, white universal veil. Lamellae white with cream tint. Stipe white. Partial veil median, white, descendant, membranous. Universal veil at stipe base a thin, white membranous free limb at the top of the tapered basal bulb. Spores amyloid, cylindric. Universal veil on pileus with inflated cells dominating, filamentous hyphae also present. Clamp connections present throughout.

Phenology. Fruiting period is December or probably after heavy rain.

Distribution and habitat. Gregarious in sandy soil in Mallee Woodland and Shrublands. Occurs on the Coolgardie Southern Cross COO02 IBRA subregion (Department of the Environment 2013).

Conservation status. To be listed as Priority One (poorly known species) under Conservation Codes for Western Australian Flora (Tanya Llorens pers. comm.).

Etymology. Mallee is used as a noun in apposition indicating the Mallee Woodland and Shrubland habitat, where the basidiomes barely emerge above the soil surface.

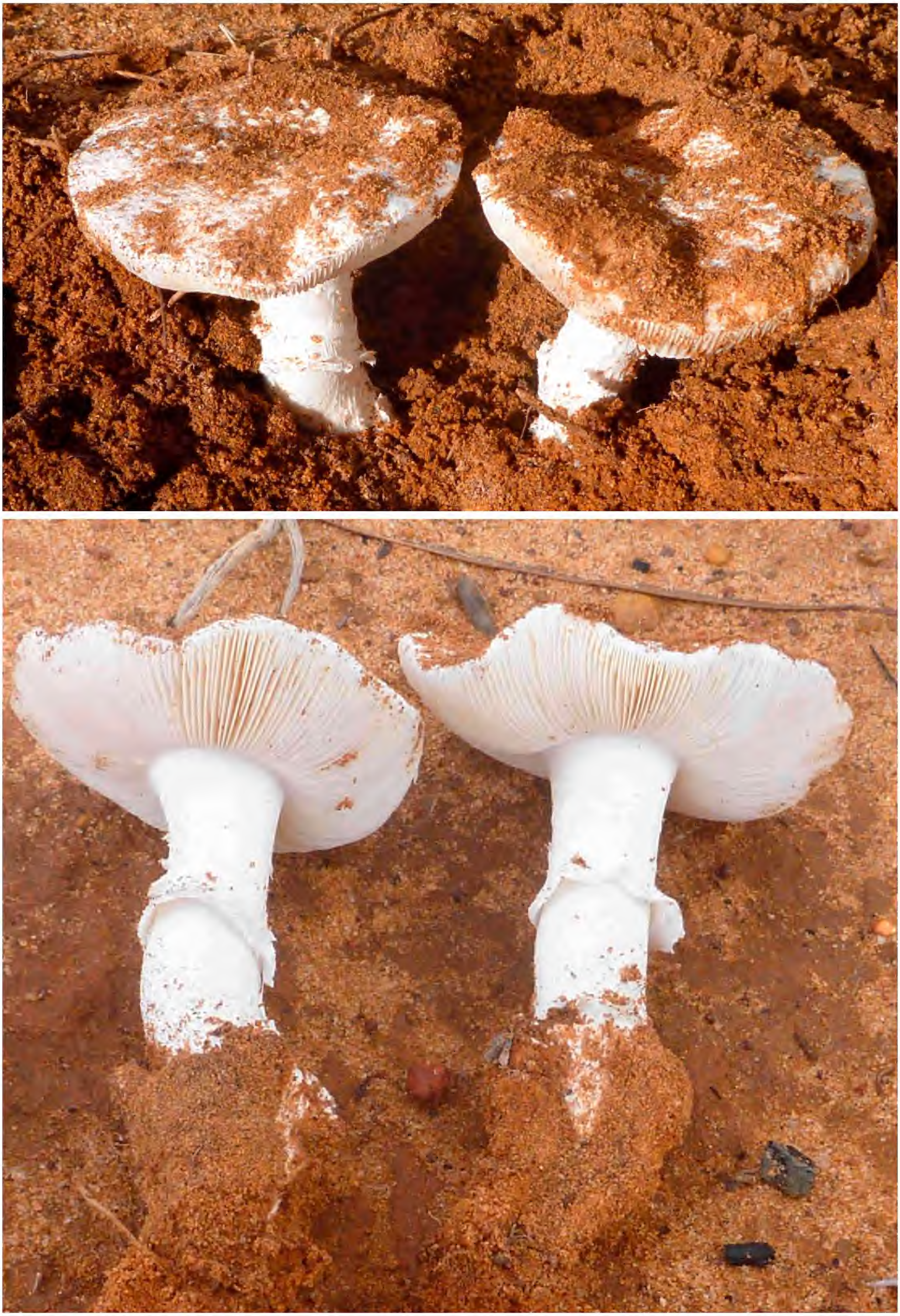

Figure 7. *Amanita mallee* basidiomes, *M.D. Barrett* F48/12 (*holo*: PERTH 09472797). Photographs M.D. Barrett.

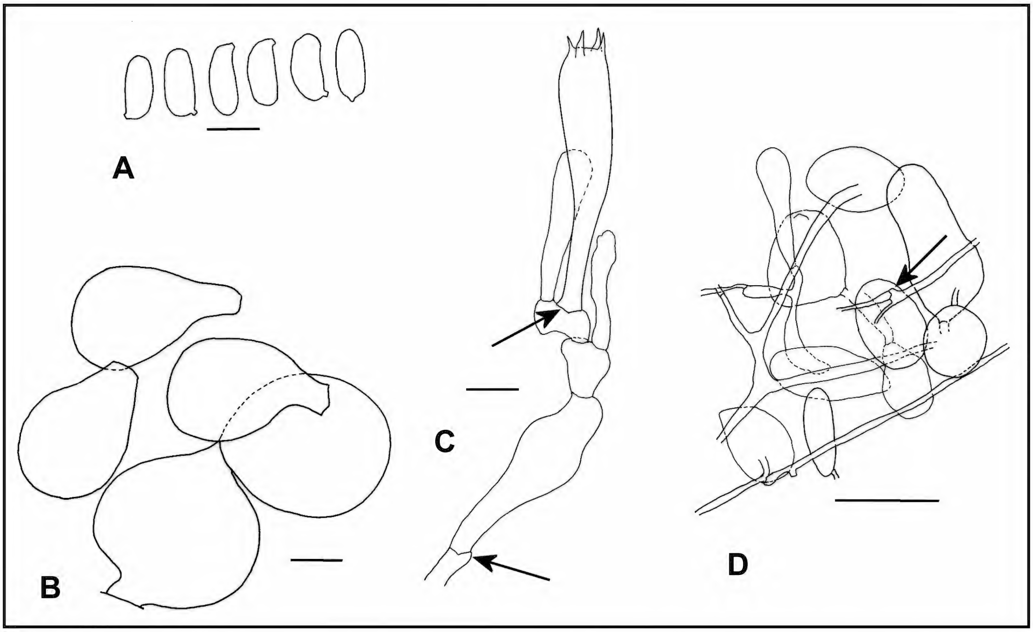

Figure 8. *Amanita mallee*. A – spores from lamella; B – marginal cells; C – basidia; D – universal veil gentle squash. Scale bars = 10 µm (A–C); 50 µm (D); clamp connections indicated by arrows. Images from *M.D. Barrett* F48/12 (*holo*: PERTH 09472797).

Table 5. Percentage difference between *ITS* clones from *A. mallee* and *A. carneiphylla* AD282179. The *ITS* region is 571–610 base pairs long.

Collection	Number of clones	***A. mallee*** **PERTH 09472797**	***A. carneiphylla*** **AD282179**
A. mallee PERTH 09472797, OP235475–80, OP235490	7	0.5–8.0	
A. carneiphylla AD282179, MN919212–16	5	22.8–24.4	0.4–1.2

Notes. *Amanta mallee* clusters close to *A. carneiphylla* AD282179 (Figures 1, 2). A comparison of cloned haplotypes of the *ITS* region from *A. mallee* shows there is considerable variation between the clones; they differ by 0.5–8.0% within an individual (Table 5). Sequences from *A. mallee* and *A. carneiphylla* AD282179 differ by 22.8–24.4%, indicating they are not the same.

We are not aware of any species in Australia that are morphologically similar to *A. mallee* and have amyloid spores. *Amanita grossa* Sacc. has large white basidiomes, but ellipsoid not cylindric spores (Bas 1969; Reid 1980; Grgurinovic 1997), whilst *A. conicobulbosa* Cleland has elongate to cylindric spores (*A. mallee* **Q** = 2.09–2.26, *A. conicobulbosa* **Q** = 1.7–2.1 (Bas 1969)). *Amanita lesueurii* E.M.Davison has elongate to cylindric spores, but lacks clamp connections; it is a member of sect. *Arenariae.* Although currently known only from the type collection, *A. mallee* is distinctive both morphologically and molecularly, and on this basis is described as a new species.

Amanita validiuscula E.M.Davison, Giustiniano & K.Syme, *sp. nov.*

Type: Shire of Cuballing, Western Australia [precise locality withheld for conservation reasons], 13 May 2016, *E.M. Davison & P.J.N Davison* EMD 35-2016 (*holo*: PERTH 09480056). [MB845578].

Pileus 54–115 mm wide, up to 14 mm thick, convex becoming plane with slightly depressed centre, margin non-striate, appendiculate, white to ivory white, without surface staining or bruising. *Universal veil on pileus* adnate, floccose, as thick crustose layer or patches to 2 mm thick, white. *Lamellae* adnexed to adnate, close to subcrowded, ivory (4B2), 5–15 mm broad, margin concolorous, fimbriate; lamellulae frequent, in several lengths, truncate or rounded truncate. *Stipe* 70–100 mm long, 30–35 mm wide, cylindric or narrowing upwards, white, surface smooth or fibrillose. *Partial veil* superior to median, descendent, flaring, striate above, thick or thin, white. *Bulb* 50–65 × 40–50 mm, turbinate becoming fusiform or tapered, white. *Remains of universal veil at top of bulb* a short free limb or rings or scales, white. *Pileus and stipe context* white, unchanging, stipe solid. *Odour* none. *Spore deposit* white. (Figure 9)

Basidiospores [140/7/2] (8–)8.5–11(–11.5) × 6–7.5(–8) µm, (**L** = 8.9–10.6 µm; **L′** = 9.6 µm; **W** = 6.4–7.3 µm; **W′** = 6.8 µm; Q = (1.23–)1.29–1.58(–1.83); **Q** = 1.39–1.48; **Q′** = 1.42), hyaline, colourless, thin-walled, smooth, amyloid, ellipsoid occasionally broadly ellipsoid or elongate, contents monoguttulate or granular; apiculus sublateral, cylindric or tapered, *c.* 1 × 1 µm, truncate. *Pileipellis* up to 170 µm thick with colourless gelatinised suprapellis up to 120 µm thick and pale yellow subpellis, consisting of filamentous hyphae and frequent to infrequent vascular hyphae (inflated cells not observed), filamentous hyphae 3–10 µm wide, thick-walled, walls hyaline, gelatinising, contents colourless, radially orientated; vascular hyphae 2–11 µm wide, colourless or brownish yellow; clamp connections infrequent. *Pileus context* consisting of dominant filamentous hyphae, frequent inflated cells and frequent to infrequent vascular hyphae, filamentous hyphae 3–25 µm wide with widest constricted at septa, thin-walled, colourless; inflated cells to 235 × 20 µm, thin-walled, cylindrical or clavate or ventricose, terminal, colourless; vascular hyphae 3–8 µm wide, occasionally branched, pale yellow or brownish yellow; clamp connections infrequent to frequent. *Lamella trama* bilateral, divergent. *Central stratum* consisting of filamentous hyphae and infrequent vascular hyphae (inflated cells not observed), filamentous hyphae 3–15 µm wide, thin walled, colourless, axially orientated; vascular hyphae 3–5 µm wide, colourless; clamp connections frequent. *Subhymenial base* with angle of divergence *c.* 30° from central stratum, with filamentous hyphae following a smooth curve to subhymenium, consisting of dominant filamentous hyphae, inflated cells and infrequent vascular hyphae; filamentous hyphae 3–15 µm wide, widest close to subhymenium and constricted at septa, thin-walled, colourless; inflated cells up to 80 × 20 µm, thin-walled, clavate or cylindrical or ventricose, colourless; vascular hyphae 2–6 µm wide, occasionally branched, colourless; clamp connections frequent to abundant. *Subhymenium* ramose, with basidia arising terminally from narrow hyphae or barely inflated hyphal segments 3–12 µm wide; clamp connections frequent to abundant. *Lamella edge tissue* sterile, with inflated cells frequent, to 25–40 × 8–22 µm, clavate, pyriform or cylindrical, colourless, some disarticulating. *Basidia* [40/2/2] (45–)48–66(–71) × 11–15(–16) µm, thin-walled, colourless, *c.* 85% 4-spored, *c.* 15% 3-spored, sterigmata to 7 × 2 µm, clamp connections frequent. *Universal veil on pileus, thin basal layer* (not always present), elements radially orientated, consisting of filamentous hyphae (inflated cells and vascular hyphae not observed), filamentous hyphae 3–5 µm wide, colourless; clamp connections not observed. *Universal veil on pileus, thick distal layer* with elements with somewhat upright orientation, consisting of frequent or dominant filamentous hyphae, dominant or frequent inflated cells and infrequent vascular hyphae, filamentous hyphae 3–20 µm wide, colourless, gelatinising; inflated cells up to 85 × 65 µm when ovoid or up to 120 × 25 µm when clavate or up to 120 × 20 µm when cylindric or up to 70 × 40 µm when ellipsoid or up to 180 × 40 µm when

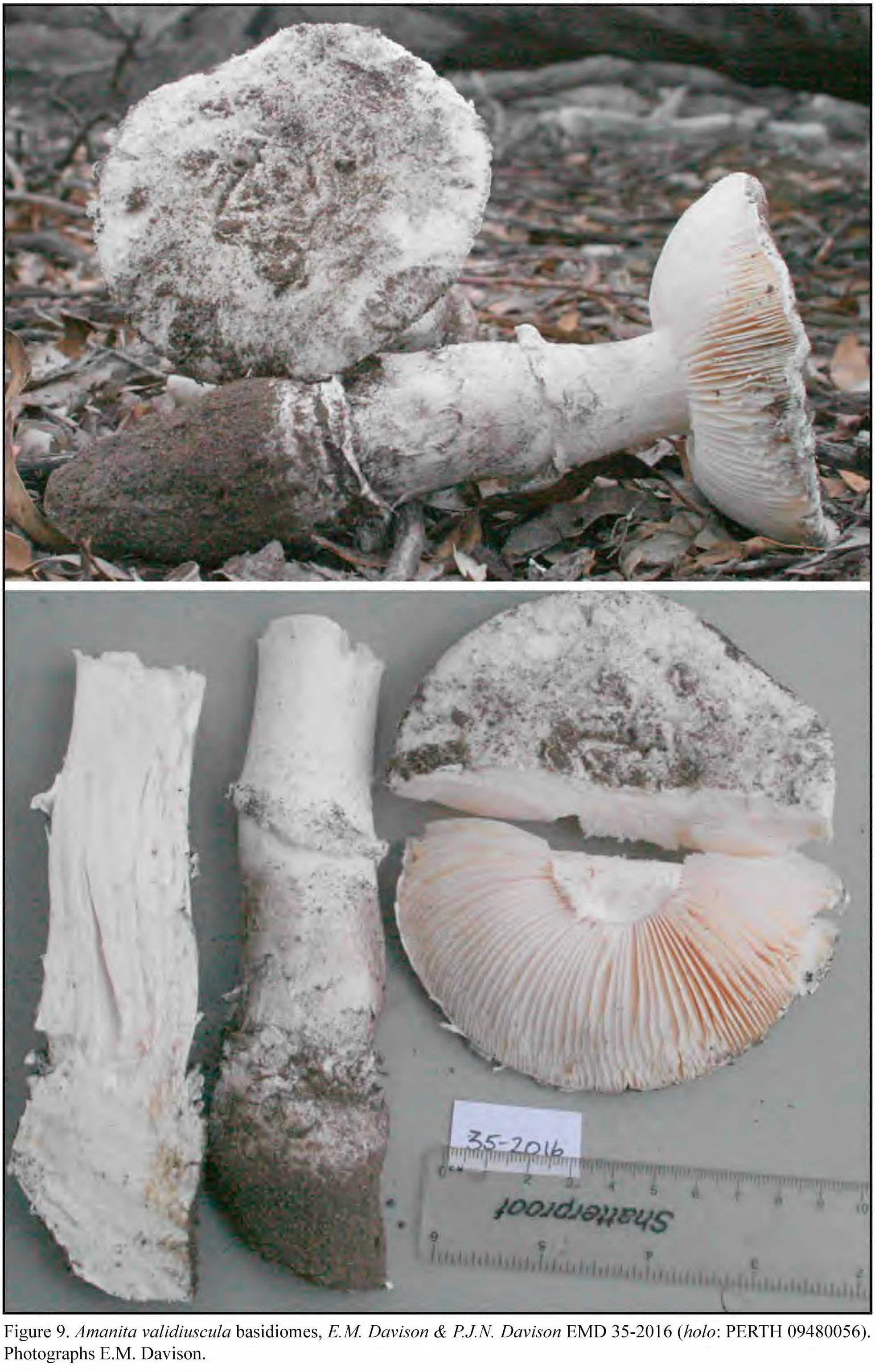

Figure 9. *Amanita validiuscula* basidiomes, *E.M. Davison & P.J.N. Davison* EMD 35-2016 (*holo*: PERTH 09480056). Photographs E.M. Davison.

ventricose, terminal, or occasionally in chains of up to three cells, colourless, gelatinising; vascular hyphae 4–10 µm wide, colourless or pale yellow; clamp connections infrequent. *Universal veil on stipe base* not layered, elements with somewhat axial orientation, consisting of dominant or frequent filamentous hyphae, frequent or dominant inflated cells and infrequent vascular hyphae, filamentous hyphae 3–12 µm wide, colourless, gelatinising; inflated cells up to 80 × 30 µm when clavate or up to 100 × 55 µm when pyriform or up to 80 × 55 µm when ovoid, terminal, colourless; vascular hyphae 4–10 µm wide, colourless or pale yellow; clamp connections infrequent. *Stipe context* longitudinally acrophysalidic, consisting of frequent filamentous hyphae, dominant acrophysalides and frequent vascular hyphae, filamentous hyphae 2–8 µm wide, colourless; acrophysalides to 420 × 30 µm, clavate or cylindric or ventricose, terminal, colourless, gelatinising; vascular hyphae 3–12 µm wide, occasionally branched, colourless or yellow; clamp connections infrequent. *Partial veil* incoherent; consisting of dominant or equal filamentous hyphae, frequent or equal inflated cells and frequent to infrequent vascular hyphae, filamentous hyphae 3–8 µm wide, colourless, disarticulating; inflated cells up to 50 × 12 µm when clavate or up to 55 × 25 µm when pyriform or up to 50 × 12 µm when ventricose, colourless; vascular hyphae 3–9 µm wide, occasionally branched, pale yellow; clamp connections infrequent. (Figure 10)

Diagnostic features. Basidiomata medium to large. Pileus white to ivory with thick, crustose or patchy, white universal veil. Lamellae ivory. Stipe thick, white. Partial veil superior to median, white, descendant, membranous. Universal veil at stipe base as white rings or scale or a short free limb at the top of the fusiform or tapered basal bulb. Spores amyloid, ellipsoid. Universal veil on pileus of dominant inflated cells and filamentous hyphae. Clamp connections present throughout.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 11 Sep. 2008, *K. Syme* 2107 (PERTH 08106290).

Phenology. Fruiting period is May to September.

Distribution and habitat. Gregarious in sandy soil in native vegetation; nearby plants include *Acacia aneura, A. ramulosa, Brachychiton gregoryii, Eucalyptus wandoo.* Occurs in the Avon wheatbelt Katanning AVW02 and Yalgoo Tallering YL02 IBRA subregions (Department of the Environment 2013).

Conservation status. To be listed as Priority Two (poorly known species) under Conservation Codes for Western Australian Flora (Tanya Llorens pers. comm.).

Etymology. From the Latin *validiusculus* meaning somewhat stout, referring to its stocky appearance.

Notes. Depending upon which gene region is analysed, *A. validiuscula* clusters close to an undescribed species from New South Wales, *A.* sp-AUS20 (Figure 1), or to *A. hiltonii* and *A. preissii* (Figures 2A, 2C). A comparison of cloned haplotypes of the *ITS* region from *A. validiuscula* shows there is considerable variation between the clones; they differ by 0.2–3.6% within an individual (Table 6). Sequences from *A. validiuscula* and *A.* sp-AUS20 differ by 9.6–10.1%, indicating they are not the same.

Amanita validiuscula is of similar colour and size to *A. grossa* and both have amyloid, ellipsoid spores and clamp connections, however, the universal veil on the pileus of *A. validiuscula* is a thick crustose layer or patches, not thin- crust- to patch-like remnants or of scattered, conical warts, as described for *A. grossa* (Bas 1969; Grgurinovic 1997). Reid (1980) describes the remains of the universal veil on the pileus of *A. grossa* as being composed of abundant oleiferous hyphae (vascular hyphae) whilst in *A. validiuscula* these are infrequent.

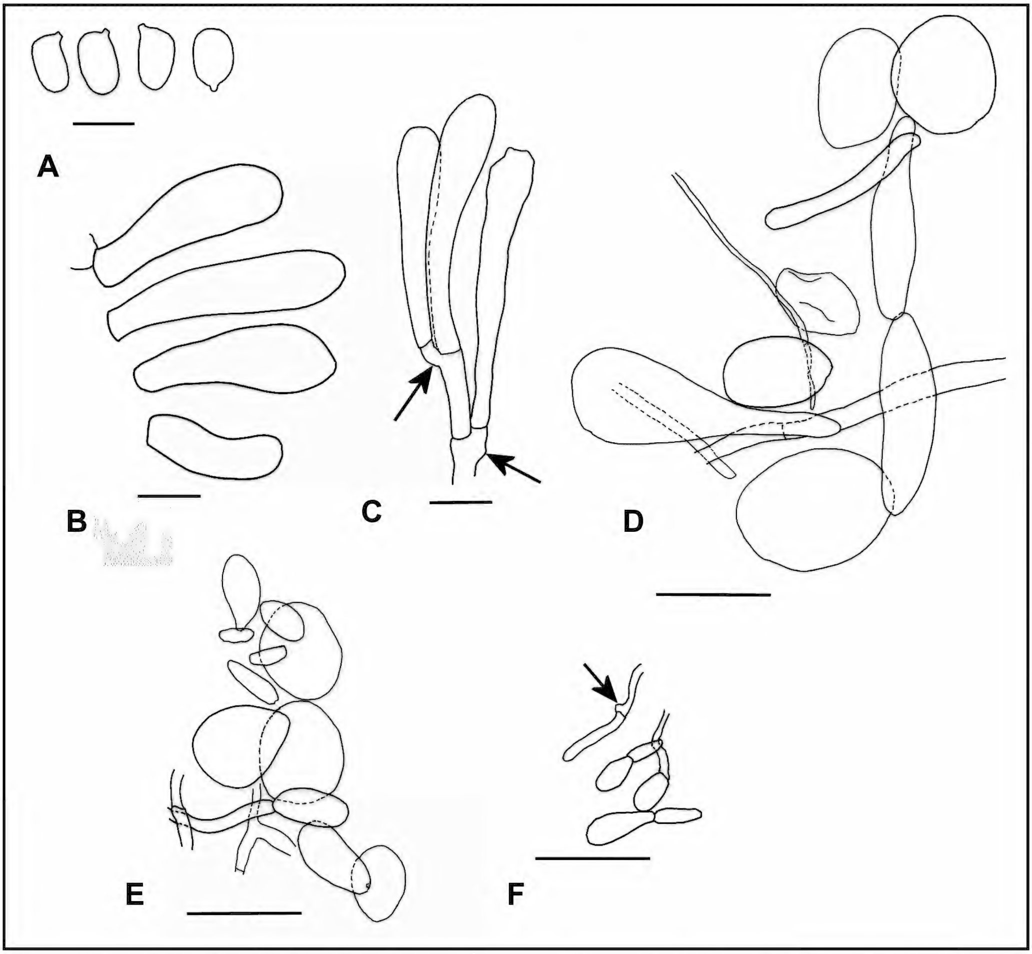

Figure 10. *Amanita validiuscula*. A – spores from print; B – marginal cells; C – basidia; D – universal veil gentle squash; E – universal veil at stipe base unsquashed; F – partial veil gentle squash. Scale bars = 10 µm (A–C); 50 µm (D–F); clamp connections indicated by arrows. Images from *E.M. Davison & P.J.N. Davison* EMD 35-2016 (*holo*: PERTH 09480056).

Table 6. Percentage difference between *ITS* clones from *Amanita validiuscula* and sequences of *A.* sp-AUS20. The *ITS* region is 598–613 base pairs long.

Collection	Number of clones	*A. validiuscula* PERTH 09480056	*A.* sp-AUS20	
			ON817223	ON817224
A. validiuscula PERTH 09480056, OP235502–05, OP235508	5	0.2–3.6		
A. sp-AUS20 ON817223		9.7–10.1		
ON817224		9.6–10.0	0.3	

Amanita validiuscula differs from *A. conicobulbosa* because the spores are ellipsoid (**Q** = 1.39–1.48) not elongate to cylindric (**Q** = 1.7–2.1 (Bas 1969)). It differs from *A. hiltonii* because it lacks a conspicuous appendiculate pileus margin (Davison & Giustiniano 2020), and *nuLSU* sequences cluster differently (Figure 1). On this basis, we describe *A. validiuscula* as a new species.

Discussion

The four new species described in this paper have been confirmed as members of sect. *Roanokenses* (Figure 1). They differ in macroscopic appearance (Figures 3, 5, 7 and 9), microanatomy (Figures 4, 6, 8 and 10), and molecular sequences (Figures 1 and 2). Like other members of sects. *Arenariae* and *Roanokenses* we have studied (Davison & Giustiniano 2020; Davison *et al.* 2017b; 2020; 2021), cloning shows the *ITS* region is much more variable than for clones recorded by Hughes *et al.* (2013).

Amanita spp. such as *A. preissii* and *A. xanthocephala* (Berk.) D.A.Reid & R.N.Hilton are amongst the earliest species described from Australia. Their macroscopic descriptions were appropriate at that time, although they would be considered inadequate by today's standards. If the type specimen is well-preserved, it will enable careful description of the microanatomy, as exemplified by Bas (1969). The Cleland collections are extremely important for documenting many species new to science, however, as Reid (1980) pointed out, they pose many difficulties for the taxonomist. Cleland's descriptions were based on a number of collections that have subsequently been found to be of more than one species (Bas 1969; Reid 1980); also, a type collection was not designated because this was not required at the time. This has led to confusion, with some of his names being applied to collections that clearly differ from the original description or nominated lectotype. An example is the uncertainly of the identity of *A. angustispora*; with the misidentification of collections BRIP 23378, BRIP 809253 and UNSW 82/47 by Wood (1997) as *A. angustispora* even though spore shape and presence of clamp connections differ from ADW 9193, the nominated lectotype (E.M. Davison, unpublished observations). The uncertainty over the identity of these Cleland types could be resolved if usable DNA is obtained from these historic collections.

Two of the species we have described (*A. mallee* and *A. validiuscula*) occur in semi-arid shrublands throughout Australia. There are probably many undescribed amanitas in this poorly collected habitat. They are likely to fruit in abundance following heavy rain, however, their low, scarcely emergent stature means they could be easily overlooked (Figure 11).

We have followed Cui *et al*. (2018), in using concatenated datasets of *nuLSU, rpb2*, β-tubulin, *ef1-α* and β-tubulin gene regions where available, to look at deeper relationships between species. Cui *et al*. (2018), have shown that sect. *Arenariae*, within subgenus *Amanitina*, is Gondwanan. The concatenated data (Figure 2D) show a well-supported clade that only includes species from Australia and New Zealand, which may also be of Gondwanan origin. Similarly, we have identified a clade from sect. *Phalloideae* as Gondwanan (Davison *et al*. 2017a). There may be other, unrecognised, Gondwanan clades within *Amanita*.

Acknowledgements

This work was supported by the Australian Biological Resources Study Grants CN211-40 and CN216-04, by Lotterywest Grant Application 421011392, and the Western Australian Naturalists' Club Gift Fund. We thank N.L. Bougher for his constructive suggestions in a draft of this manuscript, and two anonymous referees for their constructive suggestions that have improved the manuscript.

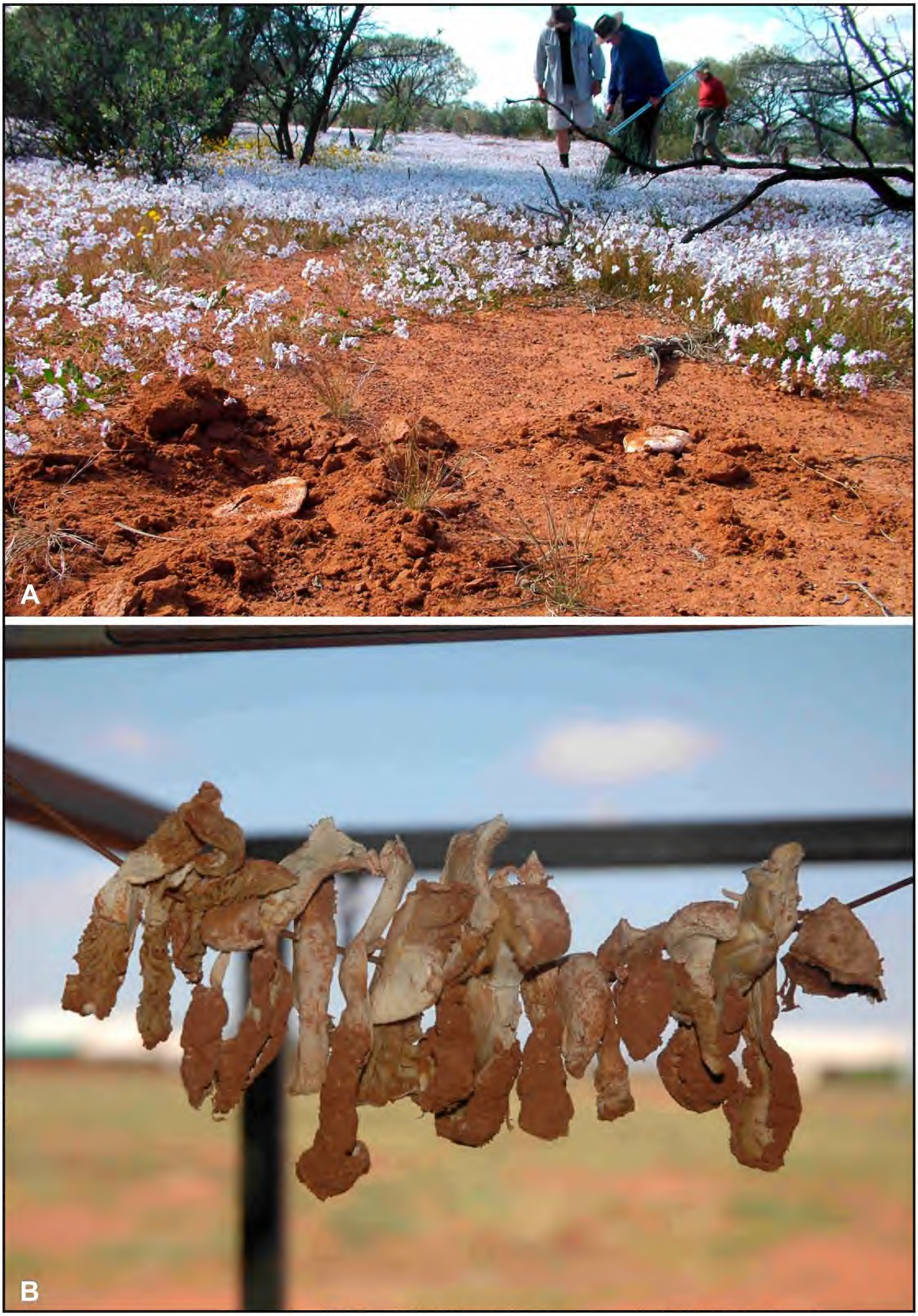

Figure 11. *Amanita validiuscula*, fruiting (A) and drying (B), Sep. 2008, *K. Syme* 2107 (PERTH 08106290). Photographs A: B. Muir, B: K. Syme.

References

Bas, C. (1969). Morphology and subdivision of *Amanita* and a monograph of its section *Lepidella*. *Persoonia* 5: 285–579.

Cleland, J.B. (1927). Australian fungi: notes and descriptions – No. 6. *Transactions of the Royal Society of South Australia* 51: 298–306.

Cleland, J.B. (1931). Australian fungi: notes and descriptions – No. 8. *Transactions of the Royal Society of South Australia* 55: 152–160.

Cui, Y-Y., Cai, Q., Tang, L.P., Liu, J-W. & Yang, Z.L. (2018). The family Amanitaceae: molecular phylogeny, higher-rank taxonomy and the species in China. *Fungal Diversity* 91: 5–230.

Davison, E.D. (2011). *Amanita ochroterrea* and *Amanita bruneiphylla* (Basidiomycota), one species or two? *Nuytsia* 21: 177–184.

Davison, E.M. & Giustiniano, D. (2020). *Amanita hiltonii* (Amanitaceae), a common but frequently misidentified mushroom in southwestern Australia, and a reconsideration of *A. albifimbriata* and *A. brunneibulbosa*. *Muelleria* 39: 59–73.

Davison, E.M., Giustiniano, D., Bougher, N.L., McGurk, L.E. & Watkin, E.L.J. (2021). Additions to *Amanita* (Amanitaceae, Agaricales) section *Arenaria* from southwestern-Australia. *Australian Systematic Botany* 34: 541–569.

Davison, E.M., Giustiniano, D., Busetti, F., Gates, G.M. & Syme, K. (2017a). Death cap mushrooms from southern Australia: additions to *Amanita* (Amanitaceae, Agaricales) section *Phalloideae* Clade IX. *Australian Systematic Botany* 30: 371–389.

Davison, E.M., Giustiniano, D. & Haska, J.F. (2020). Clarification of the type locality of *Amanita peltigera* (Agaricales, Amanitaceae), phylogenetic placement within subgenus *Amanitina*, and an expanded description. *Swainsona* 33: 51–61.

Davison, E.M., Giustiniano, D., McGurk, L.E., Syme, K. & Robinson, R.M. (2015). *Amanita drummondii* and *A. quenda* (Basidiomycota), two new species from Western Australia, and an expanded description of *A. walpolei*. *Nuytsia* 25: 1–13.

Davison, E.M., Giustiniano, D., McGurk, L.E., Watkin, E.L.J. & Bougher, N.L. (2017b). Neotypification and redescription of *Amanita preissii* (Basidiomycota), and a reconsideration of the status of *A. griseibrunnea*. *Nuytsia* 28: 193–204.

Davison, E.M., McGurk, L.E., Bougher, N.L., Syme, K. & Watkin, E.L.J. (2013). *Amanita lesueurii* and *A. wadjukiorum* (Basidiomycota), two new species from Western Australia, and an expanded description of *A. fibrillopes*. *Nuytsia* 23: 589–606.

Department of the Environment (2013). *Australia's bioregions (IBRA)*. IBRA7, Commonwealth of Australia. https://www.environment.gov.au/land/nrs/science/ibra#ibra [accessed 10 Aug. 2022].

Grgurinovic, C.A. (1997). *Larger Fungi of South Australia.* (The Botanic Gardens of Adelaide and State Herbarium: Adelaide.)

Hughes, K.W., Petersen, R.H., Lodge, D.J., Bergemann, S.E., Baumgartner, K., Tulloss, R.E., Lickey, E. & Cifuentes, J. (2013). Evolutionary consequences of putative intra- and interspecific hybridization in agaric fungi. *Mycologia* 105: 1577–1594.

Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitution through comparative studies of nucleotide sequences. *Journal of Molecular Evolution* 16: 111–120.

Kornerup, A. & Wanscher, J.H. (1983). *Methuen Handbook of Colour.* 3rd edn. (Methuen: London.)

McGurk, L.E., Giustiniano, D., Davison, E.M. & Watkin, E.J. (2016). *Amanita wadulawitu* (Basidiomycota), a new species from Western Australia, and an expanded description of *A. kalamundae. Nuytsia* 27: 21–30.

Miller, O.K. Jr. (1991). New species of *Amanita* from Western Australia. *Canadian Journal of Botany* 69: 2692–2703.

Miller, O.K. Jr. (1992). Three new species of *Amanita* from Western Australia. *Mycologia* 84: 679–686.

Reid, D.A. (1980). A monograph of the Australian species of *Amanita* Pers. ex Hook. (Fungi). *Australian Journal of Botany; Supplementary Series* No. 8: 1–97.

Royal Botanic Garden, Edinburgh (1969). *Flora of British fungi: colours identification chart*. (Her Majesty's Stationery Office: Edinburgh.)

Schoch, C.L., Seifert, K.A., Huhndorf, S., Robert, V., Spouge, J.L., Levesque, C.A., Chen, W. & Fungal Barcoding Consortium (2012). Nuclear ribosomal internal transcribed spacer (ITS) region, a universal DNA barcode marker for Fungi. *Proceedings of the National Academy of Sciences* 109: 6241–6246.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011). Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution* 28: 2731–2740.

Travaré, S. (1986). Some probabilistic and statistical problems on the analysis of DNA sequences. *Lectures on Mathematics in the Life Sciences* 17: 57–86.

Tulloss, R.E. (2000). *Notes on methodology for study of Amanita (Agaricales).* http://www.amanitaceae.org/content/uploaded/pdf/methodsb.pdf [accessed 11 Aug 2016].

Tulloss, R.E. (2022). *Amanita angustispora* (http://www.amanitaceae.org/?Amanita%20angustispora [accessed 7 June 2022].

Wood, A.E. (1997). Studies in the genus *Amanita* (Agaricales) in Australia. *Australian Systematic Botany* 10: 723–854.

Yang, Z.L., Cai, Q. & Cui, Y-Y. (2018). Phylogeny, diversity and morphological evolution of Amanitaceae. *Biosystematics and Ecology-Series* 34: 359–380.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01047

Nuytsia 34: 93–94

Published online 21 March 2023

Lectotypification of *Astartea arbuscula* and *A. fascicularis* (Myrtaceae)

Juliet A. Wege[1] and Barbara L. Rye

Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[1]Corresponding author, email: Juliet.Wege@dbca.wa.gov.au

SHORT COMMUNICATION

Taxonomic treatments of a range of genera from Myrtaceae tribe Chamelaucieae are gradually being published online for the *Flora of Australia*. The following two lectotypifications are made as part of the recent synthesis of *Astartea* DC. (Rye 2022).

Astartea arbuscula (R.Br. ex Benth.) Rye, *Nuytsia* 16(1): 152 (2006); *Baeckea arbuscula* R.Br. ex Benth., *Fl. Austral.* 3: 79 (1867). *Type*: King George Sound, heaths between Oyster and Princess Royal Harbours, Western Australia, December 1801, *R. Brown s.n.* (*lecto*, here designated: BM 000758991!; *isolecto*: CANB 278733!, E 00801186 image!, K 000821969!, K 000821970!, NSW 497662!).

Typification. When *Baeckea arbuscula* was transferred to *Astartea* DC., a syntype at BM was incorrectly cited as the holotype (Rye 2006). In their detailed synthesis of the collections of Robert Brown, Mabberley *et al.* (2022: 398) note that this syntype, which comprises ample material and bears Brown's annotations, would be a good candidate for lectotypification. We concur and effect this lectotypification above.

Astartea fascicularis (Labill.) DC., *Prodr.* 3: 210 (1828); *Melaleuca fascicularis* Labill., *Nov. Holl. Pl.* 2: 29–30, t. 170 (1806); *Baeckea fascicularis* (Labill.) Nied., in A. Engler & K. Prantl, *Nat. Pflanzenfam.* III, 7: 99. (1893). *Type*: 'in capite Van-Diemen' [probably collected on Observatory Island, Archipelago of the Recherche, Western Australia, 11–18 December 1792], *J.J.H. de Labillardière s.n.* (*lecto*, here designated: FI 011333 image!; *isolecto*: BM 001015089 image!, B (B-W 14369-01 0) image!, CAS 0026080 image!, G 00659440 *n.v.*, G 00659492 *n.v.*, GH 00069950 image!, HAL 0089688 image!, M 0137440 image!, NY 00405319 image!, P 05263231 image! [RH fragment ex Herb. Maire], P 05263234 image!, P 05263236 image!).

Typification. Type material of *A. fascicularis* was not viewed when the genus was revised in 2013 and the holotype was presumed to be at FI (Rye 2013: 234); however, numerous syntypes have since come to light. The specimen at FI, which bears extensive descriptive annotations by Labillardière and sketches of the floral parts, is selected here as an appropriate lectotype.

© Department of Biodiversity, Conservation and Attractions 2023

ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

References

Mabberley, D.J., Moore, D.T. & Wajer, J. (2022). The Robert Brown handbook. A guide to the life and work of Robert Brown (1773–1858) Scottish botanist. *Regnum Vegetabile* Vol. 160. (Koeltz Botanical Books: Glashütton, Germany.)

Rye, B.L. (2006). New combinations and lectotypifications for the south-western Australian genus *Astartea* (Myrtaceae). *Nuytsia* 16(1): 149–156.

Rye, B.L. (2013). A revision of the south-western Australian genus *Astartea* (Myrtaceae: Chamelaucieae). *Nuytsia* 23: 189–269.

Rye, B.L. (2022). *Astartea*, in J.A. Wege (ed.), *Flora of Australia*. Australian Biological Resources Study, Department of Climate Change, Energy, the Environment and Water: Canberra. https://profiles.ala.org.au/opus/foa/profile/Astartea

Nuytsia The journal of the Western Australian Herbarium
https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 95–98
https://doi.org/10.58828/nuy01048 Published online 27 April 2023

Acacia armigera (Fabaceae), a new, geographically restricted wattle from the Coolgardie bioregion of Western Australia

Kevin R. Thiele[1], Robert W. Davis[2,4] and Geoff T.B. Cockerton[3]

[1]School of Biological Sciences, The University of Western Australia,
35 Stirling Hwy, Crawley Western Australia 6009
[2]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[3]Western Botanical, PO Box 169, Mount Helena Western Australia 6082
[4]Corresponding author, email: robert.davis@dbca.wa.gov.au

SHORT COMMUNICATION

Acacia Mill. is Australia's most species-rich, and one of its most iconic, genera. The genus has a significant centre of species diversity in the south-west and adjacent semi-arid parts of Western Australia (Hnatiuk & Maslin 1988). Sustained taxonomic research in this area, particularly by Bruce Maslin at the Western Australian Herbarium, has led to more than 390 new Western Australian *Acacia* taxa being described in the last 50 years, many of which are conservation-listed (Western Australian Herbarium 1998–). There remain around 75 informally named taxa in Western Australia that require further taxonomic research, some of which are also potentially rare. One such species is dealt with in this paper.

The new species described below was first noted by one of us (GC) and Sophie Fox of Western Botanical in 2015 during flora surveys of gold leases in the Mount Dimer area. It was regarded at the time of collection that it was likely to be new, although the plants were without flowers. The species was collected from the same location in 2016 (again sterile), and subsequently phrase-named at the Western Australian Herbarium as *Acacia* sp. Southern Cross (G. Cockerton et al. WB 38518). Further field work in 2021 led to a collection of adequate type material, allowing it to be described here.

Acacia armigera R.W.Davis, K.R.Thiele & Cockerton, *sp. nov.*

Type: Mount Dimer area, north of Southern Cross, Western Australia [precise locality withheld for conservation reasons], 31 August 2021, *K.R. Thiele & G. Cockerton* KRT 5719 (*holo*: PERTH 09457879; *iso*: CANB, MEL).

Acacia sp. Southern Cross (G. Cockerton et al. WB 38518), Western Australian Herbarium, in *FloraBase*, https://florabase.dpaw.wa.gov.au/ [accessed 3 May 2022].

Dense, rounded, rigid, sub-glaucous *shrubs* 0.8–1 m high, 1–2 m wide. *Branchlets* terete, smooth, with two rows of dense, minute, patent to ascending white hairs to 0.2 mm long, glabrous to sparsely hairy between the rows of hairs, tardily glabrescent. *Stipules* absent. *Phyllodes* on short stem projections,

© Department of Biodiversity, Conservation and Attractions 2023 ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

rigid, pentagonal with equal faces, patent to ascending, straight or shallowly curved, 13–34 mm long, 1–1.2 mm diam., each with a small patch of dense, white hairs at the base on the adaxial surface, the remaining surface with very sparse, appressed or sub-appressed white hairs, glabrescent; *longitudinal nerves* 5, scarcely raised, with no anastomoses; *apex* excentrically pungent-pointed with a long, fine, acicular point to 3 mm long; *pulvinus* absent; *gland* 1, elliptic, pit-like, *c.* 0.5 mm long, 8.5–13 mm from the base of the phyllode. *Inflorescences* simple, globular, paired-axillary, pedunculate, bright yellow; *peduncles* erect to ascending, slender, 4.5–7.5 mm long, glabrous or occasionally with sparse appressed hairs, subtended by a strongly cupped, caducous bract 1–1.4 mm long that is abaxially minutely pubescent; *heads* 3–4.5 mm diam. when dried, 17–23-flowered; *bracteoles* oblanceolate to spathulate, 0.7–0.9 mm long, glabrous. *Flowers* 5-merous; *calyx c.* half as long as petals, the sepals free or very shortly united, glabrous, the lobes spathulate, smooth; *corolla* 1.4–1.6 mm long, nerveless, glabrous. *Pods* terete, 32–40 mm long, 2.5–3 mm wide, thick-crustaceous, curved, acute at both ends, with a sparse covering of appressed white hairs, dark red while immature becoming dark brown at maturity. *Seeds* longitudinally arranged in the pods; mature seeds not seen. (Figure 1)

Characteristic features. Dense, rounded, rigid, sub-glaucous *shrubs*. *Branchlets* terete, with two rows of dense, patent to ascending hairs to *c.* 0.2 mm long, glabrous to sparsely hairy between the rows of hairs; stipules absent. *Phyllodes* rigid, epulvinate, pentagonal with equal faces, patent to ascending, straight or shallowly curved, 13–34 mm long, 1–1.2 mm diam., with 5 scarcely raised nerves; *apices* excentrically and finely pungent-pointed. *Inflorescences* simple, globular, paired-axillary, on slender, usually glabrous *peduncles* 4.5–5 mm long; *heads* 3–4.5 mm diam. when dried. *Flowers* 5-merous; *calyx c.* half as long as petals, the sepals free or very shortly united. *Pods* terete, 32–40 mm long, 2.5–3 mm wide, with sparse, appressed, white hairs. *Seeds* longitudinally arranged.

Other specimen examined. WESTERN AUSTRALIA: [locality withheld for conservation reasons] 16 Oct. 2016, *G. Cockerton, D. Brassington & D. Leach* WB 38518 (PERTH).

Distribution and habitat. *Acacia armigera* is currently known from a single location near Mount Dimer, north of Southern Cross. At this site it grows in a tall open eucalypt woodland on medium red-brown clay with a discontinuous pizolitic lag gravel, in a broad, non-incised drainage line. Associated species include *Eucalyptus salubris*, *E. salmonophloia*, *E. transcontinentalis*, *Eremophila hamulata*, *E. caperata*, *Atriplex bunburyana, Templetonia sulcata* and *Olearia muelleri*.

Phenology. The type specimen was flowering in late August; young pods were also present at this time.

Etymology. The epithet is from the Latin *armiger* (bearing thorns or armed), in relation to its spiny phyllodes.

Common name. Fierce Wattle.

Conservation status. *Acacia armigera* is listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), as *A.* sp. Southern Cross (G. Cockerton et al. WB 38518). The area where it occurs is relatively sparingly collected, and it is likely that the species is at least slightly more widespread than is currently known.

Affinities. *Acacia armigera* is morphologically somewhat similar to *A. asepala* Maslin*, A. inamabilis* E.Pritz. and *A. calcarata* Maiden & Blakely, sharing with these species five-nerved, epulvinate, rigid, pungent phyllodes that are regularly pentagonal in section. *Acacia armigera* differs from all three in

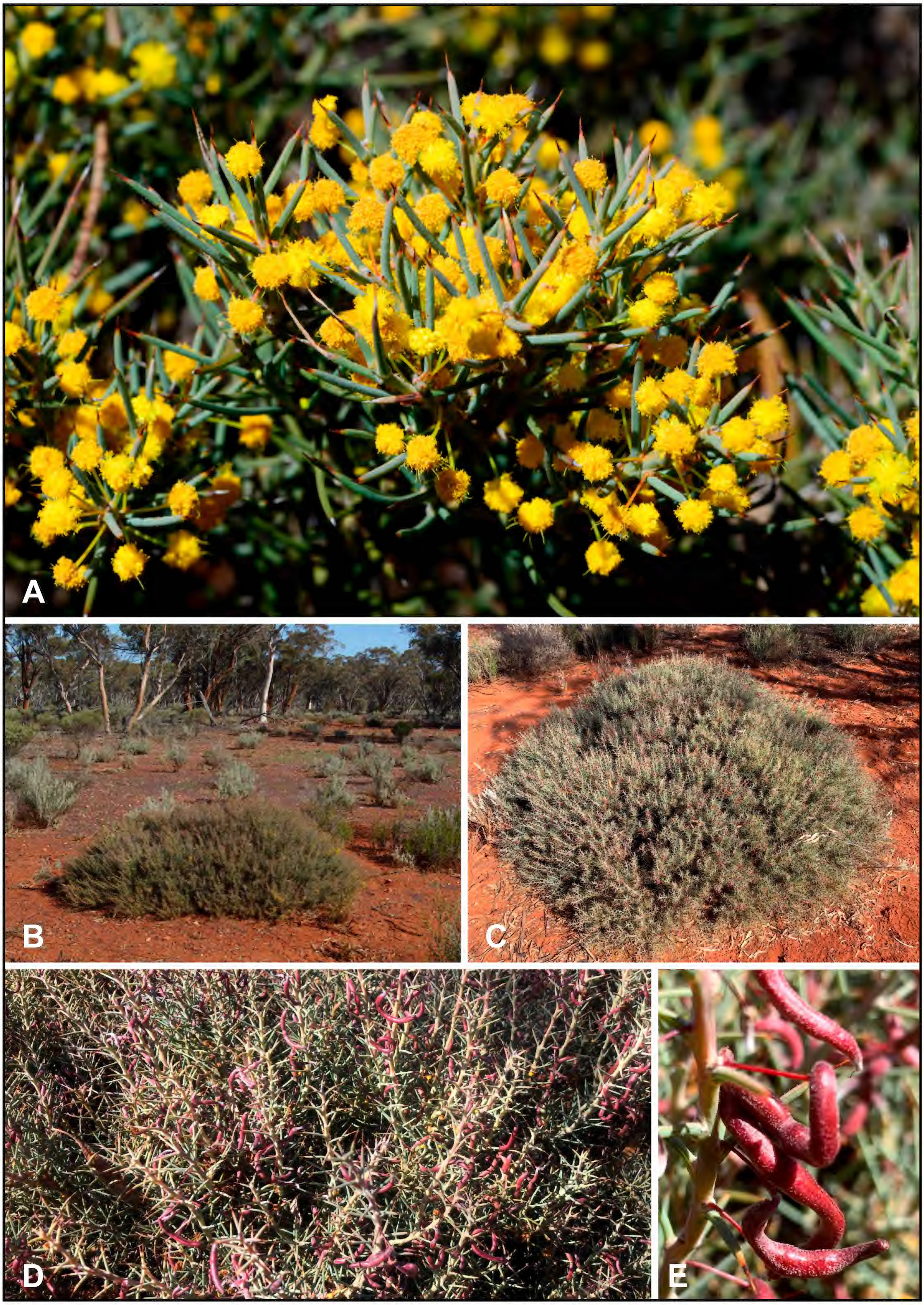

Figure 1. *Acacia armigera* at the type locality. A – flowering branch; B, C – shrubs in habitat; D – fruiting branches; E – immature fruits. All photos G. Cockerton (except top, K.R. Thiele).

having branchlets with two distinct rows of dense hairs, stipules absent, sepals free to very shortly united, and pods narrow (2.5–3 mm wide), terete and sparsely appressed-pubescent. The other taxa have glabrous branchlets (excepting two specimens of *A. inamabilis* that have evenly pubescent branchlets and phyllodes). Sepals are absent in *A. asepala*, while in *A. inamabilis* and *A. calcarata* they are united for ½ to ¾ of their length. Both *A. inamabilis* and *E. calcarata* have prominent, persistent, spinose stipules. Pods in *A. asepala*, *A. calcarata* and *A. inamabilis* are more than 5 mm wide, non-terete and glabrous.

Acknowledgements

We thank Sophie Fox, Daniel Brassington and David Leach for assistance in the field and Julia Percy-Bower for excellent curatorial assistance at the Western Australian Herbarium. WATTLE (Maslin 2018) was used to help ascertain that this is a new species and to indicate morphologically similar taxa.

References

Hnatiuk, R. & Maslin, B.R. (1988). Phytogeography of *Acacia* in Australia in Relation to Climate and Species-Richness. *Australian Journal of Botany* 36: 361–383.

Maslin, B.R. (coordinator) (2018). *WATTLE, Interactive Identification of Australian Acacia. Version 3*. (Australian Biological Resources Study, Canberra; Department of Biodiversity, Conservation and Attractions, Perth; Identic Pty. Ltd., Brisbane.)

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au/ (Accessed 27 March 2023).

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 99–103
https://doi.org/10.58828/nuy01052 Published online 27 April 2023

A new, geographically restricted species of *Acrotriche* (Ericaceae: Epacridoideae: Styphelieae) from the central south coast of Western Australia and an updated key to species

Michael Hislop[1], Katherine Walkerden[2] and Julie Waters[2]

[1] Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2] Shire of Esperance, PO Box 507, Esperance, Western Australia 6450
[1] Corresponding author, email: Michael.Hislop@dbca.wa.gov.au

SHORT COMMUNICATION

Acrotriche R.Br. is a small, morphologically distinctive genus characterised by usually greenish flowers with long hair tufts towards the corolla lobe apices, in combination with often dense hairs within the throat of the corolla tube. The species described here brings to 19 the number now recognised Australia-wide (Council of Heads of Australasian Herbaria 2006–) with eight occurring in Western Australia (Hislop 2007; Hislop 2010). The new species was discovered by K. Walkerden and J. Waters in September 2021 during a detailed flora survey as part of an environmental impact assessment for a local government infrastructure project in the Cascade area.

Acrotriche platycarpa Hislop, *sp. nov.*

Typus: Cascade area, Western Australia [precise locality withheld for conservation reasons], 14 July 2022, *K. Walkerden & J. Waters* KSW9222A (*holo*: PERTH 09486356; *iso*: CANB, K, MEL, NSW).

Spreading *shrubs* to *c.* 60 cm high and 120 cm wide, multi-stemmed at base from a fire-tolerant rootstock. Young *branchlets* with a moderately dense indumentum of patent to retrorse hairs, to *c.* 0.1 mm long. *Leaves* spirally arranged, usually steeply antrorse, slightly glaucous on younger leaves; apex long-mucronate, pungent, the mucro 0.4–1.2 mm long; base cuneate to ± rounded; petiole 0.5–1.2 mm long, shortly hairy on the adaxial surface and usually also on the margins, ± glabrous on the abaxial surface; lamina usually narrowly oblong or narrowly elliptic, occasionally narrowly ovate, 7–15 mm long, 1.5–2.3 mm wide, distinctly convex adaxially with variably recurved margins, longitudinal axis slightly incurved to slightly recurved; surfaces strongly discolorous; adaxial surface shiny, glabrous or with sparse, short hairs towards the base, venation not evident; abaxial surface much paler, matt, glabrous, with 5 or occasionally 7 primary veins that are strongly highlighted against the paler, ± flat or slightly sunken intercostal tissue, intercostal distance between midrib and first vein on either side 0.2–0.3 mm; margins glabrous or with sparse, minute hairs < 0.05 mm long. *Inflorescence* erect to sub-pendulous, axillary or arising from bare nodes a little below the current leaves; axis 1.8–4.5 mm long, 2–6-flowered, terete, with a moderately dense indumentum, terminating in a rather obscure bud-rudiment; flowers erect or spreading, sessile. *Fertile bracts* depressed-ovate, 0.6–1.0 mm long, 0.9–1.3 mm wide, subtended by 7–10 sterile bracts which obscure much of the surface of the axis.

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

Bracteoles broadly elliptic to transversely elliptic or broadly ovate to depressed-ovate, 1.0–1.5 mm long, 1.0–1.3 mm wide, keeled, obtuse; abaxial surface scabrous about the keel, otherwise glabrous; margins minutely ciliolate. *Sepals* ovate to broadly ovate, 1.5–2.2 mm long, 1.2–1.5 mm wide, obtuse; adaxial surface glabrous; abaxial surface straw-coloured or pale green, sometimes flushed pink, glabrous, with prominent venation, at least at fruiting; margins ciliolate with hairs < 0.05 mm long. *Corolla tube* green, sometimes partially flushed pink-purple, ellipsoid to obovoid, longer than the sepals, 2.4–3.0 mm long, 1.5–2.0 mm wide, external surface glabrous, internal surface with 5 densely hairy, raised, cushion-like outgrowths[1] just below the lobe bases, the remainder glabrous. *Corolla lobes* pale green, shorter than the tube, 1.6–2.0 mm long, 0.8–1.0 mm wide, spreading from close to the base and ± straight to gently recurved, external surface glabrous, internal surface with a subapical, ± gently curved band of straight ± smooth hairs, the remainder finely papillose or sometimes with a few long basal hairs. *Anthers* fully exserted from the corolla tube and held at right angles to the floral axis at dehiscence, 0.6–1.0 mm long, apex ± truncate. *Filaments* terete, 0.5–0.6 mm long, sparsely hairy in the lower half, attached to the anther 1/2–2/3 above base, adnate to the tube just below the sinuses. *Nectary* annular, ± truncate to shallowly lobed, 0.3–0.5 mm long, glabrous. *Ovary* globose or depressed-globose, 0.6–1.0 mm long, 0.7–1.0 mm wide, glabrous, 4–6-locular (usually 5-). *Style* 0.8–1.3 mm long, glabrous, well-differentiated from the ovary apex, included within the corolla tube; stigma not expanded. *Fruit* strongly depressed-obovoid, 3.4–4.0 mm long, 5.5–7.0 mm wide, much longer than the sepals, gynophore absent; surface barely rugulose, longitudinally ribbed, mesocarp poorly developed; style shed or not, at maturity. (Figure 1)

Diagnostic characters. *Acrotriche platycarpa* is distinguished by the following character combination: leaves narrowly oblong or narrowly elliptic, sharply pungent, with recurved margins; inflorescences 2–6-flowered, axillary, or arising from bare nodes just below the current leaves; fruit strongly depressed-obovoid 3.4–4.0 mm long, 5.5–7.0 mm wide.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 11 Jan. 2022, *K. Walkerden & B. Husbands* KSW0222 (PERTH); 11 Jan. 2022, *K. Walkerden & B. Husbands* KSW0422 (PERTH); 11 Jan. 2022, *K. Walkerden & B. Husbands* KSW0522 (PERTH); 14 July 2022, *K. Walkerden & Julie Waters* KSW9222B; 24 Sep. 2021, *J. Waters & K. Walkerden* KSW5221 (PERTH).

Distribution and habitat. Currently known only from a small area south-east of Cascade in the south of the Mallee bioregion. Grows in alkaline, grey, fine sand or light loam over clay, sometimes with laterite. Associated vegetation is mallee woodland over dense shrubs, with the following species among those recorded in close proximity: *Eucalyptus forrestiana*, *E. kessellii*, *Melaleuca subfalcata*, *M. societatis*, *M. hamata*, *Daviesia aphylla* and *Beyeria sulcata*. Other epacrids in the immediate area are *Styphelia intertexta*, *Lissanthe rubicunda*, *Leucopogon canaliculatus*, *L.* sp. Newdegate, *Acrotriche* sp. Israelite Bay and a narrow-leaved variant of *A. cordata*.

Phenology. The only flowering collection was made in the middle of July, but it is clear from this material that flowers would continue to be produced at least into August. Mature fruit has been collected in January.

Etymology. From the Greek *platys* (flat, wide) and *-carpus* (fruited), a reference to the distinctive fruit shape of the new species.

---

[1] This character is illustrated in Hislop 2007: 291, figure 1I

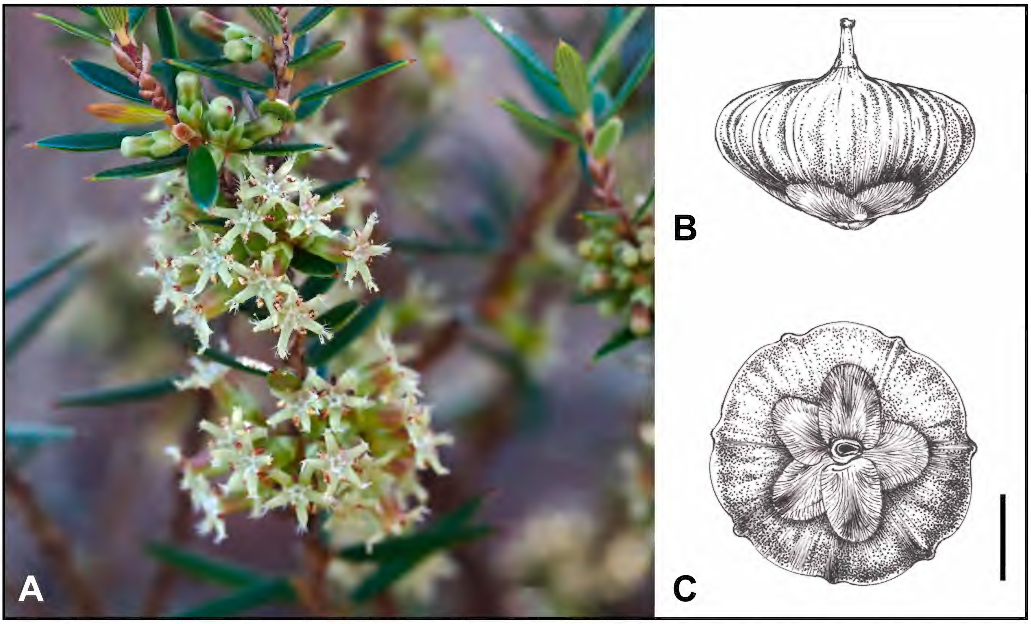

Figure 1. *Acrotriche platycarpa*. A – flowering branchlet *in situ*.; B – fruit, side view; C – fruit, view from below. Scale bar = 2 mm. Vouchers *K. Walkerden & J. Waters* KSW9222A (A), *K. Walkerden & B. Husbands* KSW0522 (B, C). Photograph by Katherine Walkerden. Drawings by Hung Ky Nguyen.

Conservation status. At this stage the species is only known from a roadside population of a couple of dozen plants scattered over about 1.5 kilometres. However, the habitat appears to be a common one in the general area and this part of the south coast of Western Australia is relatively well-vegetated. The potential for discovery of new populations therefore appears quite high. *Acrotriche platycarpa* will be listed as Priority One under Conservation Codes for Western Australian Flora (T. Llorens pers. comm.).

Affinities. *Acrotriche ramiflora* R.Br. is the only other Western Australian species that has similarly narrow, sharply mucronate leaves with recurved margins. Because it also occurs in near south-coastal localities it is therefore the congener most likely to be confused with *A. platycarpa*. The new species differs from *A. ramiflora* in having a fewer-flowered inflorescence (2–6-flowered *cf.* 6–11 in *A. ramiflora*) which is either axillary or arising from bare nodes a little below the current leaves (*cf.* obviously ramiflorous with the flowers usually produced well below the current leaves). An obvious difference is in the fruit, with *A. platycarpa* having a strongly depressed-obovoid drupe, 5.5–7 mm wide, compared to the globose or broadly obovoid fruit, 3–4 mm wide, of *A. ramiflora*. Even in the sterile condition though the two should still be readily distinguishable. Leaves of the new species are usually steeply antrorse in orientation, with the adaxial and abaxial surfaces strongly discolorous and with the veins on the abaxial surface contrasting strongly with the much paler intercostal tissue, giving a striped appearance. In *A. ramiflora* by contrast the leaf orientation is shallowly antrorse to shallowly retrorse, the two surfaces less obviously discolorous and the abaxial veins only slightly darker than the intercostal tissue.

Acrotriche parviflora (Stschegl.) Hislop also has strongly discolorous leaves and is known to occur as far east as the Ravensthorpe area. However, the two should not otherwise be confused because that species has innocuous leaf tips and the corolla lobe hairs are in a strongly crescent-shaped formation rather than a gently curved band.

Updated key to the Western Australian species of *Acrotriche*

1. Corolla white, hairs evenly distributed across the lobes and into the throat of the tube (Borden–Wellstead–Ongerup) .... **A. dura**

1: Corolla predominantly greenish, occasionally yellowish-green or greenish suffused purple; lobes usually with hairs confined to subapical tufts, occasionally with very sparse long hairs scattered across the surface; tube with 5 hair tufts in the throat

  2. Leaf with a long, pungent mucro

    3. Leaves ovate, occasionally narrowly ovate, 3–6 mm wide, most, or at least some leaves with cordate bases. Corolla throat hairs arising from unmodified epidermal cells. Fruiting endocarp with deep, sharply angular longitudinal ribs (coastal and subcoastal: Toolinna Cove–South Australian border) .... **A. patula**

    3: Leaves narrowly ovate, narrowly oblong, narrowly elliptic or linear, 1.3–3.2 mm wide, with cuneate or rounded bases. Corolla throat hairs arising from 5 raised, cushion-like outgrowths. Fruiting endocarp smooth or if with longitudinal ribs apparent then not as above

      4. Leaves convex, the margins clearly recurved on dried specimens, intercostal distance between midrib and first veins on either side 0.2–0.3 mm

        5. Leaves shallowly antrorse to shallowly retrorse. Inflorescences mostly 6–11-flowered, usually arising from bare nodes well below the leaves. Fruit globose to broadly obovoid, 3–4 mm wide (Stirling Range–Ravensthorpe; Cape le Grand–Israelite Bay) .... **A. ramiflora**

        5: Leaves usually steeply antrorse. Inflorescence 2–6-flowered, arising from leaf axils or from bare nodes a little below the current leaves. Fruit strongly depressed-obovoid, 5.5–7 mm wide (Cascade area) .... **A. platycarpa**

      4: Leaves slightly concave, flat or slightly convex, if the margins ± recurved on dried specimens the intercostal distance between midrib and first veins *c.* 0.5 mm (Kondinin–Gt Eastern Hwy–Bremer Range–Lake King) .... **A. lancifolia**

  2: Leaf apex usually obtuse or subacute, if occasionally acute then with an innocuous tip, never pungent

    6. Corolla lobe hairs largely confined to a subapical tuft, the latter arranged in a crescent-shaped formation. Ovary 7–10-locular (Stirling Range–Ravensthorpe; outliers at Tarin Rock and Dongolocking) .... **A. parviflora**

    6: Corolla lobe hairs either mostly in a subapical tuft or not, but if so then the tuft a ± straight transverse band. Ovary 4–5-locular

      7. Leaves pruinose, broadly ovate to depressed-ovate, broadly elliptic to transversely elliptic, or occasionally broadly obovate to depressed-obovate. Corolla lobes 0.6–0.7 mm long, with rather sparse hairs scattered across the surfaces. Corolla throat hairs in rather sparse tufts arising from unmodified epidermal cells (Ravensthorpe area) .... **A. orbicularis**

      7: Leaves not pruinose, variable in shape, whether ovate, elliptic or obovate, rarely broadly so. Corolla lobes 1.2–1.9 mm long, with hairs in a well-defined subapical tuft (occasionally a very few hairs may be present below the tuft). Corolla throat hairs dense, arising from 5 raised cushion-like outgrowths (mostly coastal, from Leeman along the W and S coasts to Great Australian Bight, but extending well inland in parts of central south coast) .... **A. cordata**

References

Council of Heads of Australasian Herbaria (2006–). *National Species List*. *Acrotriche* R.Br. https://biodiversity.org.au/name/apni/ 74477 [accessed 15 March 2023].

Hislop, M. (2007). A new species and a new combination in *Acrotriche* (Ericaceae: Styphelioideae: Styphelieae), with keys to the Western Australian members of the genus and its closest relative *Lissanthe*. *Nuytsia* 16: 285–297.

Hislop, M. (2010). A new locally endemic species of *Acrotriche* (Ericaceae: Styphelioideae: Styphelieae). *Nuytsia* 20: 19–25.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 105–109
https://doi.org/10.58828/nuy01055 Published online 27 April 2023

George Maxwell's collecting locality – Eyre's Relief

Lesley Brooker

P.O. Box 518, Kalamunda, Western Australia 6926
Email: lesmikebrooker@bigpond.com

SHORT COMMUNICATION

Several of the plant specimens gathered by 19th century naturalist George Maxwell bear the collecting locality 'Eyre's Relief' or 'Eyre's Water Relief'. This has usually been interpreted in the literature (e.g. Gardner 1960) and herbarium specimen databases (AVH 2023) as meaning the place where, in April 1841, Edward John Eyre found water in the sandhills east of the Baxter Cliffs; i.e. Eyre or Eyre's Sandpatch, where the stone Eyre Telegraph Station was built in 1897 and where the Eyre Bird Observatory is now located (32°14' 47" S, 126° 18' 5" E). However, this interpretation is problematic since many of the plant taxa in question have never subsequently been found at Eyre. The general location of Eyre's Relief is important to know as it is the type locality of at least 11 species (Table 1) and potentially marks the eastern distributional limit of other species (Nelson 1974). Evidence provided here suggests that it lies near the western end of the Baxter Cliffs, another area where Eyre is known to have sourced fresh water.

The Baxter Cliffs stretch for 160 km along the southern coastline of Western Australia from Point Culver in the west to Twilight Cove in the east (Figure 1), presenting a sheer drop of 80 m to the surf below. West of Point Culver, the cliffs retreat inland (as Wylie Scarp) leaving a stretch of sand hills, sand flares, salt pans and low vegetation between Wylie Scarp and the ocean. At the eastern end, the cliffs turn inland forming an escarpment that separates the Hampton Tableland from the Roe Plain.

Eyre travelled westward along the southern coastline in company with his overseer, John Baxter, Wylie, an Aborigine from King George Sound, and Joey and Yarry, two Aboriginal youths from New South Wales (Eyre 1845). After finding water in the sandhills at Eyre and filling their containers, they travelled along the top of the Baxter Cliffs. About 70 km west of Eyre, John Baxter was shot dead by one of the New South Wales Aborigines, both of whom then absconded with some of the stores and equipment, including two of the firearms. Desperate to find more water and to put some distance between themselves and the two boys, Eyre and Wylie continued along the clifftop. Finally, at the western end of the cliffs, Eyre wrote 'a native road led us down a very steep part of the cliffs, and we descended to the beach. The wretched horses could scarcely move … By perseverance we still got them slowly along, for two miles from the base of the cliffs, and then turning in among the sand-drifts, to our greatest joy and relief, found a place where the natives had dug for water; thus at twelve o'clock on the seventh day since leaving the last depot, we were again encamped at water, after having crossed 150 miles of a rocky, barren, and scrubby table land.' (Eyre 1845, Vol II: 17).

In April 1863 George Maxwell accompanied an expedition led by Charles Edward Dempster to explore eastward from Albany along the southern coastline. His plant collections from Eyre's Relief

© Department of Biodiversity, Conservation and Attractions 2023 ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

Table 1. Details of locations, habitat and dates given on specimens collected by George Maxwell from 'Eyre's Relief'. ^ = not otherwise recorded from Eyre (AVH 2023); * = type material.

Taxon	Specimen	Location, habitat and date
Acacia pulchella R.Br.^	MEL 0049525A	Eyre's Relief, sand flare. Top of bank.
Adenanthos cuneatus Labill.	MEL 2169421A	Below the bank on loose dry lime stone soil.
	MEL 2169422A	Eyre's Relief. Near the bank on loose lime stone soil. Sand drifts.
Andersonia macranthera F.Muell.^	*MEL 0233230A	Near Eyre's Relief sand flares. Great Bight. Winter 1863.
Clematis pubescens Hügel ex Endl.^	MEL 2209637A	Extremity of the Great Bight. Eyre's Relief Sand Flares. Eucalyptus thickets. Sandy soil.
	MEL 2209646A	Eyre's Relief Sand Flares. Among Eucalyptus thickets. Sandy soil.
Dodonaea stenozyga F.Muell.	MEL 2250951A	Behind Eyre's Relief. Growing in sand hummocks, sandy places. 1863.
Eremophila decipiens Ostenf. subsp. *decipiens*	MEL 0079216A	Eyre's Relief. Sand hummocks.
	MEL 0079217A	Eyre's Relief. Lime stone formation, base of the bank. Sand flares.
Eucalyptus micranthera F.Muell. ex. Benth.^	*NSW 345964	'… on a white sandpatch, two miles westward from Eyre's Relief. This latter place is today known as Eyre…' (Gardner 1960)
	*MEL 0075550A	Israelite Bay to Eyre's Relief. Sand flares. Sandy hummocks.
Eucalyptus scyphocalyx (F.Muell. ex. Benth.) Maiden & Blakely^	*MEL 1008918A	Eyre's Relief Camp. White sand flare.
	*NSW 17795	Eyre's Relief Camp.
Goodenia concinna Benth.	*MEL 0023674A	Base of the bank behind Eyre's Relief sand hummocks.
Glycocystis beckeri (F.Muell.) Chinnock^	*MEL 0095562A	Loose lime stone under the bank opposite Eyre's Relief sand flares.
Grevillea sparsiflora F.Muell.	*MEL 0074750A	Lime stone ridges near Eyre's Relief sand flares.
	*MEL 0074750B	Lime stone ridges near Eyre's Relief sand flares.
Grevillea tripartita subsp. *macrostylis* (F.Muell.) Makinson^	MEL 0065700A	Eyre's Relief. Sandy places. Sand plains.
Halgania andromedifolia Behr & F.Muell.	MEL 0656853A	Eyre's Relief sand flares. In front of the bank. Dry decomposed lime stone soils.
Hybanthus floribundus subsp. *curvifolius* E.M.Benn.^	MEL 0026942A	Between the bank and Eyre's Relief sand hummocks. 1863.
	MEL 0026976A	Between the bank and Eyre's Relief sand flare.
Leucopogon obovatus subsp. *revolutus* (R.Br.) Hislop^	MEL 0078333A	Eyre's Water Relief. White sand hummocks. Sandy places.
Olearia exiguifolia (F.Muell.) F.Muell. ex. Benth.	*MEL 1543516A	On the top of the bank behind Eyre's Relief sand hummocks.

Taxon	Specimen	Location, habitat and date
Phebalium lepidotum (Turcz.) Paul G.Wilson^	*MEL 0004798A	Sandy ridges between the bank and Eyre's Relief sand hummocks.
Philotheca fitzgeraldii (C.R.P.Andrews) Paul G.Wilson^	MEL 0004035A	Between Eyre's Relief sand hummocks and the bank.
Senecio pinnatifolius A.Rich. var. *pinnatifolius*	MEL 2168113A	Eyre's Relief camp. Growing among sand drift hummocks.
Styphelia concinna (Benth.) F.Muell.^	*MEL 1513018A	On the table land interior of Eyre's relief sand flares. Lime stone formation.
Styphelia exserta (F.Muell.) Sleumer	MEL 1510114A	W extremity of the Great Bight. N from Eyre's Water Relief. On the top of the bank. Sand drift. Hummocks.
Styphelia hainesii F.Muell.	*MEL 0009035A	Near Eyre's Water Relief sand drift. Hummocks. Precipitous lime stone cliffs. June 1863.
Synaphea divaricata (Benth.) A.S.George^	*MEL 0687661A	Eyre's Relief. On the top of the bank. Sand flares. Lime stone tableland.

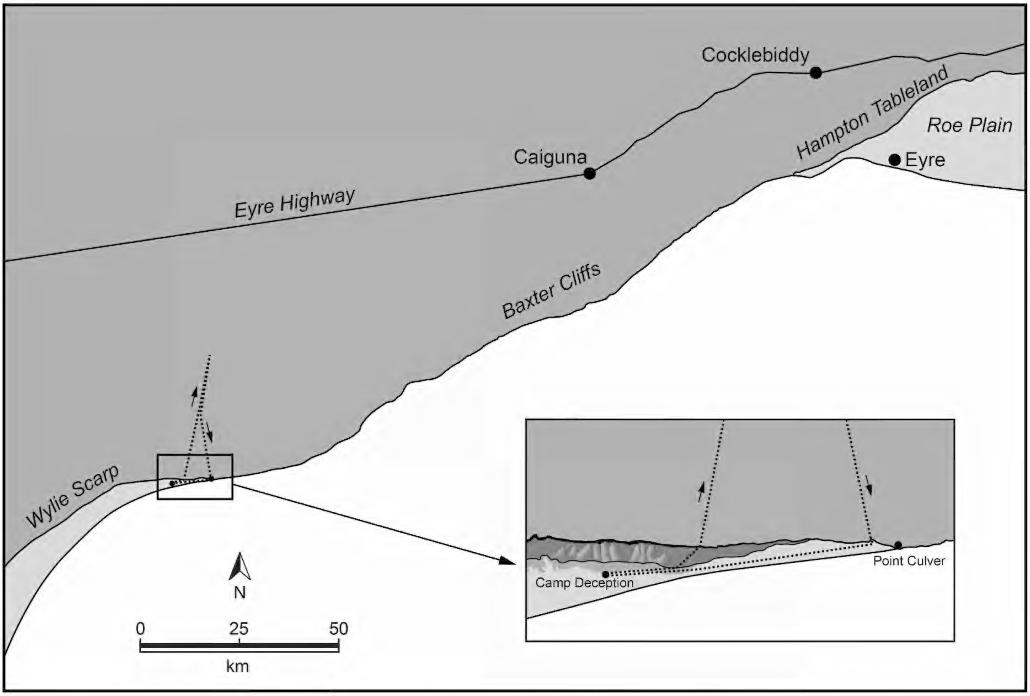

Figure 1. The location of Point Culver and Eyre relative to the Baxter Cliffs, on the south-eastern coast of Western Australia. Insert: Route taken by the Dempster party on 19–20 June 1863 and supposed location of their Camp Deception.

appear to have been made during this trip in June, although only a subset are labelled with the year and only one, *Styphelia hainesii* F.Muell., bears the month (Table 1). In early June the party travelled from Israelite Bay north-eastward as far as the western end of the Baxter Cliffs. Some of the party climbed the Wylie Scarp and travelled a further 18 miles (29 km) north before returning to the main camp. The whole party then retraced their steps to Bellinger Sandplain (on the mainland opposite Bellinger Island), where Maxwell and another man (one of the crew of the *Amelia*) left the main party and returned to Albany travelling overland by themselves.

When at their closest approach to Point Culver on 18 June 1863, the main party had halted at 'Camp Deception', 'in a valley where there is a little grass' (Dempster 1863, 2018). They had obtained water by digging 'on edge of Sand Patch'. From this description and from their subsequent movements, it is clear that Camp Deception was situated somewhere between the 'immense sand patch' of Carey (*c.* 1877) (i.e. Bilbunyah Dunes) and Point Culver. Confirmation of this can be found by plotting the route of their excursion north on 19–20 June 1863, when, on their return journey, the party descended the cliffs 'behind Point Culver' (Dempster 1863, 2018; Figure 1). This would place Camp Deception at roughly 32° 56' S, 124° 26' E or thereabouts, where there are sand hummocks, sand flares and a bank (cliff) of limestone formation, as described by Maxwell on his specimen labels. This area to the west of Point Culver was called Billabilla in the 1870s (Carey *c.* 1877).

To my knowledge, Maxwell never travelled further east along the coastline than he did during this 1863 expedition. Subsequent travellers, for example John Forrest in 1870 (Forrest 1998), John Paul Brooks in 1874 (Brooks 1874) and Henry Stuart Carey in 1876 (Carey 1877, *c.* 1877), also found water by digging in the sand hills just west of Point Culver.

Of 23 plant taxa recorded by Maxwell at or near 'Eyre's Relief', or 'Eyre's Water Relief', 13 have not otherwise been recorded at Eyre (Table 1). Moreover, the terms Eyre's Relief and Eyre's Water Relief seem to echo Eyre's sentiments of 'greatest joy and relief', while the terms 'sand flares', 'sand hummocks' and 'the bank' are a better description of the country just west of Point Culver than of the country surrounding Eyre, which is sand plain with large dunes on the seaward side and an escarpment about 9 km inland. On this basis I conclude that 'Eyre's Relief' must lie close to the western end of the Baxter Cliffs in the general vicinity of 32° 56' S, 124° 26' E and not 200 km to the east at Eyre.

Acknowledgements

I am grateful to Stephen Hopper for sharing his interest in the location of Eyre's Relief, to Juliet Wege and Peter Olde for their helpful comments and to Belinda Cale for kindly producing the figure.

References

AVH (2023). *The Australasian Virtual Herbarium*. Council of Heads of Australasian Herbaria. https://avh.chah.org.au [accessed 15 January 2023].

Brooks, J.P. (1874). *Journal of a trip to Eucla. Some of the natural features of Israelite Bay and its vicinity. In*: Royal Western Australian Historical Society (1829–1966). Collection of papers on Western Australian history, 1829–1966. (Battye Library: Perth. MN 1388, ACC 4308A/HS832.)

Carey, H.S. (1877). Notes from the Eucla Telegraph Line. *The Inquirer*, 14 February 1877.

Carey, H.S. (*c.* 1877). *South Coast of WA showing telegraph line Albany to Eucla by C.D. Price (3 Plan Set) includes H.S. Carey Field Book No.4 survey.* State Records Office, Perth. Department of Lands and Surveys, Consignment 3843, Series 233, Item 074A.

Dempster, C.E. (1863). Journal of an Expedition to Point Culver, in the Australian Bight. *The Inquirer*, 23 September 1863.

Dempster, C.E. (2018). Journal of an Expedition to Point Culver, in the Australian Bight. *In:* Bridge, P.J. & Epton, K. (eds) *Exploration Eastwards 1860–1869*. pp. 55–67. (Hesperian Press: Carlisle.)

Eyre, E.J. (1845). *Journals of the Expeditions of Discovery into Central Australia and Overland from Adelaide to King George's Sound in the years 1840–41*. (T&W Boone: London.)

Forrest, J. (1998). *Explorations in Australia*. (Friends of the State Library of South Australia: Adelaide.)

Gardner, C.A. (1960). Trees of Western Australia. *Journal of the Department of Agriculture, Western Australia*. Series 4. 1(5): 445–455.

Nelson, E.C. (1974). Disjunct plant distributions on the south-western Nullarbor Plain, Western Australia. *Journal of the Royal Society of Western Australia* 57: 105–117.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01050

Nuytsia 34: 111–123
Published online 27 April 2023

Amanita marinae (Basidiomycota), a new species from the mid-west region of Western Australia

Elaine M. Davison[1,2,4] **and Danielle Giustiniano**[3]

[1]School of Molecular and Life Sciences, Curtin University, GPO Box U1987, Perth, Western Australia 6845
[2]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[3]Curtin Medical School, Curtin University, GPO Box U1987, Perth, Western Australia 6845
[4]Corresponding author, email: e.davison@curtin.edu.au

Abstract

Davison, E.M. & Giustiniano, D., *Amanita marinae* (Basidiomycota), a new species from the mid-west region of Western Australia. *Nuytsia* 34: 111–124 (2023). *Amanita marinae* E.M.Davison & Giustiniano from sect. *Validae* (Fr.) Quél. is described from Kwongan vegetation in the Lesueur Sandplain of the mid-west region of Western Australia. It is distinguished by a white to ivory pileus; white to pale vinaceous buff universal veil; a white, membranous, flaring partial veil; amyloid elongate spores; and absence of clamp connections. Its affinities with other members of sect. *Validae* are unclear as phylogenetic analyses of nuLSU and *tef-1* sequences show affinities with northern hemisphere species, whilst comparison of ITS sequences shows affinities with an undescribed species from New Zealand. Variability in the ITS region between cloned haplotypes of *A. marinae* was less than 1% — comparable with haplotype divergence previously observed for other members of sect. *Validae*.

Introduction

Amanita Pers. is a large, cosmopolitan genus predominantly of mushrooms, but also with some sequestrate taxa, which is well represented in Australia. The species are ecologically important because most are considered to be mycorrhizal with woody plants, whilst they are important economically because some species are edible whilst others are poisonous (Cui *et al.* 2018). The genus has been monographed in Australia by Reid (1980) and Wood (1997), whilst additional mushroom species have been described and taxonomic clarifications made by Miller (1991, 1992), Grgurinovic (1997), Davison (2011), Davison and Giustiniano (2020), Davison *et al.* (2013, 2015, 2017a, 2017b, 2020, 2021, 2023) and McGurk *et al.* (2016). There are about 100 named Australian species, but many more await description.

The genus *Amanita* is defined by the presence of a membranous or friable universal veil, the microscopic characters of bilateral lamella trama and acrophysalidic stipe trama, and the ontogenetic character of schizohymenial development (Bas 1969). Identification of *Amanita* species is difficult and is based on a combination of macroscopic characters and microanatomy. However, molecular analyses have become increasingly important in identifying new species and determining relationships within the genus (Cui *et al.* 2018).

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

The genus has been recently revised by Cui *et al.* (2018) using a multi-marker data set. They recognise three subgenera: *Amanita*, *Amanitina* (E.-J.Gilbert) E.-J.Gilbert and *Lepidella* Beauseigneur, which differ in spore amyloidy and whether they are mycorrhizal or saprotrophic. Most Australian species fall within subgenus *Amanitina*, characterised by having amyloid spores and a bulb at the base of the stipe; they are all likely to be mycorrhizal. Cui *et al.* (2018) recognise six sections within *Amanitina*: sect. *Amidella* (E.-J.Gilbert) Konrad & Maubl., sect. *Arenariae* ZhuL.Yang, Y.Y.Cui & Q.Cai, sect. *Phalloideae* (Fr.) Quél., sect. *Roanokenses* Singer ex Singer, sect. *Strobiliformes* Singer ex ZhuL.Yang, Y.Y.Cui & Q.Cai, and sect. *Validae* (Fr.) Quél. These sections can be recognised morphologically by differences in the pileus margin, form of the universal veil, and presence or absence of clamp connections.

We describe here a new species from the mid-west region of Western Australia, *Amanita marinae* E.M.Davison & Giustiniano. It has characteristics of sect. *Validae* because it has a non-striate pileus margin; the stipe base is initially turbinate, becoming turbinate to rooting; the universal veil on the pileus breaks into flat patches; the partial veil is membranous and composed of dominant filamentous hyphae; the basidiospores are amyloid; and clamp connections are absent (Cui *et al.* 2018). We have used the nuclear large subunit rRNA (nuLSU) region to confirm its placement in this section because this is the only region available from GenBank for all type species of sections within subgenus *Amanitina*. We have also looked at two other regions which are used for species delimitation in *Amanita*: translation elongation factor 1-alpha (*tef-1*) and the nuclear ribosomal internal transcribed spacer (ITS). The ITS region is important because it is used as a barcode marker for species discrimination within Basidiomycota (Schoch *et al.* 2012). Our experience with Australian *Amanita* species is that this gene region can be extremely variable. For example, in sect. *Phalloideae* it failed to separate species that differ in spore shape and geographic location (Davison *et al.* 2017a), whilst in sect. *Arenariae* and sect. *Roanokenses* the base pair divergence between haplotypes from the same individual was as much as 8.1% (Davison *et al.* 2021, 2023). In this study we determined the degree of haplotype divergence in the ITS region between cloned haplotypes of *A. marinae*.

Methods

Taxonomy. The methodology used for describing the macroscopic and microscopic characters largely follows Tulloss (2000). Colour names, including the colour of spores in deposit and other shades of white to cream (designated by the letters A–G), follow Royal Botanic Garden, Edinburgh (1969); while colour codes are from Kornerup and Wanscher (1983). In the descriptions of basidiospores (and basidia), the notation [x/y/z] denotes x basidiospores measured from y basidiomes from z collections. Biometric variables for spores follow Tulloss (2000), i.e. '**L** = the average spore length computed for one specimen examined and the range of such averages, **L′** = average spore length computed for all spores measured, **W** = the average spore width computed for one specimen examined and the range of such averages, **W′** = average spore width computed for all spores measured, Q = the length/breadth for a single spore and the range of the ratio of length/breadth for all spores measured, **Q** = the average value of Q computed for one specimen examined and the range of such averages, **Q′** = the average value of Q computed for all spores measured'. Author citations follow Index Fungorum (http://www.indexfungorum.org/Names/Names.asp [accessed 30 Dec. 2022]).

Phylogenetics. DNA extraction, amplification and cloning of the ITS region, and amplification of the nuLSU (28S nuclear large subunit rRNA) region and the *tef-1* (translation elongation factor 1-alpha) gene follow the methodology in Davison *et al.* (2013, 2017b). Sequence data were assembled with Geneious v. 10.0.5 (https://www.geneious.com) and aligned with Geneious Alignment. The undescribed species was compared with the type species for sections within subgenus *Amanitina* along with some northern hemisphere and Gondwanan species from these sections. In addition, the BLAST function in Geneious (the equivalent of blastn (Altschul *et al.* 1990)) was used to identify closely related sequences, all of which were accessed from GenBank (http://www.ncbi.nlm.nih.gov/ [accessed 2 Jan. 2023]) (Tables 1 and 2).

Maximum likelihood phylogenetic trees were built using MEGA v. 5 (Tamura *et al.* 2011) following alignment with MUSCLE (Edgar 2004), with the best model for each dataset determined using the Model Function. The Tamura-Nei model (Tamura & Nei 1993) with gamma distribution rates was used for nuLSU. The Kimura 2-parameter model (Kimura 1980) with gamma distribution rates was used for *tef-1*. A consensus tree of 500 bootstrap replicates was used to obtain support values.

The differences between cloned haplotypes of the ITS region were obtained from the Distance function of an alignment in Geneious.

Results

Phylogenetics

A BLAST search for the nuLSU sequence for the novel species (which we name *A. marinae*) shows the closest match is the northern hemisphere species *A. submaculata* Peck (OP048958) with 98.7% pairwise similarity and 100% query coverage (820 base pair positions). A maximum likelihood phylogenetic tree for nuLSU shows that *A. marinae* clusters within sect. *Validae* (Figure 1). It clusters with the northern hemisphere species *A. submaculata*, *A. sepiacea* S.Imai and *A.* sp. ‘ostendemihi’ in a clade with moderate support (75%) (Figure 1). It does not cluster with the Australian and New Zealand species *A. karea* G.S.Ridl., *A. nothofagi* G.Stev., *A. luteofusca* (Cleland & E.-J.Gilbert) E.-J Gilbert, *A. luteolovelata* D.A.Reid and *A.* sp. ‘Bealey’.

A BLAST search for the *tef-1* sequence for *A. marinae* shows there are no close matches in GenBank; the closest matches are *A.* sp. ‘Bealey’ (MT977099) with 91.3% pairwise similarity and 94% query coverage, *A. citrinoindusiata* Zhu.L.Yang, Y.Y.Cui & Q.Cai (MH508746) with 89.1% pairwise similarity and 90.8% query coverage, and *A. sepiacea* (MH509073) with 88.6% pairwise similarity and 98.6% query coverage (468 base pair positions). A maximum likelihood phylogenetic tree shows *A. marinae* clusters with *A.* sp. ‘Bealey’ and *A. sepiacea*, but with poor support (Figure 2).

A comparison of five cloned haplotypes of the ITS region from *A. marinae* shows these differ by less than 1% (Table 3). A BLAST search of the ITS sequence from *A. marinae* shows the closest match is *A.* sp. ‘Bealey’ (MT863752) with 94.9% pairwise identity and 98.9% query coverage, followed by *A. sepiacea* (MW192488) with 93.9% pairwise identity and 97% query coverage.

Table 1. Voucher information and GenBank accession numbers for nuLSU sequences from type species of sections (indicated by *) and other relevant collections used to place the new species in subgenus *Amanitina*. Newly published sequences are shown in bold. nuLSU, nuclear large subunit rRNA region; SA, South Australia; WA, Western Australia.

Section	*Amanita* spp.	Voucher number	Location	nuLSU
Amidella	**A. volvata* (Peck) Lloyd	KA12-0985	Gyeonggi, Korea	KF245905
	**A. volvata*	KA12-1194	Gyeonggi, Korea	KF245906
	**A. volvata*	KA12-1367	Gyeongbuk, Korea	KF245907

Section	*Amanita* spp.	Voucher number	Location	nuLSU
	A. brunneomaculata ZhuL. Yang, Y.Y.Cui & Q.Cai	HKAS 70032	Yunnan, China	MH486411
	A. lanigera Y.Y.Cui, Q.Cai & ZhuL.Yang	HKAS 89030	Yunnan, China	MH486621
	A. parvicurta Y.Y.Cui, Q.Cai & ZhuL.Yang	HKAS 101215	Yunnan, China	MH486745
Arenariae	**A. arenaria* (O.K.Mill. & E.Horak) Justo	PERTH 07586329, VPI679 (type)	City of Albany, WA	GQ925382
	A. wadulawitu McGurk, E.M.Davison & E.L.J.Watkin	PERTH 09144390	Shire of Serpentine-Jarrahdale, WA	MN918098
	A. peltigera D.A.Reid	AD282185	Kangaroo Island, SA	MN900628
	A. peltigera	PERTH 08793514	Shire of Manjimup, WA	MN900625
Phalloideae	**A. phalloides* (Vaill. ex Fr.) Link	HKAS75773	China	JX998060
	A. djarilmari E.M.Davison	PERTH 08776067	Shire of Cuballing, WA	KY977704
	A. marmorata (Cleland & E.-J.Gilbert) E.-J.Gilbert	PERTH 08690596	Shire of Denmark, WA	KY977711
Roanokenses	**A. roanokensis* Coker	FLAS-F-60892	Florida, USA	MH620252
	A. carneiphylla O.K.Mill.	PERTH 08793530	City of Melville, WA	MN911351
	A. hiltonii D.A.Reid	PERTH 09004599	Shire of Cuballing, WA	MT364455
	A. pareparina G.S. Ridl.	JAC13371	New Zealand	MT862271
	A. preissii (Fr.) Sacc.	PERTH 08690766	Kings Park, WA	KY290654
Strobiliformes	**A. strobiliformis* (Paulet ex Vittad.) Bertill.	MB-001177	Germany	MH486895
	A. cinereopannosa Bas	RET 318-8	Maine, USA	HQ539678
	A. aspericeps Y.Y.Cui, Q.Cai & ZhuL.Yang	HKAS 77783	Guangdong, China	MH486372
	A. cinereoradicata Y.Y.Cui, Q.Cai & ZhuL. Yang	HKAS63641	Yunnan, China	MH486452
Validae	**A. excelsa* (Fr.) Bertill.	HKAS96169	Austria	MH486492
	**A. excelsa*	HKAS31510	Yunnan, China	AY436491
	**A. excelsa*	Ge 816	Sichuan, China	HQ539691
	A. citrina Pers.	BW JLR 102106-1	New Jersey, USA	HQ539679
	A. congolensis (Beeli) Tulloss, B.E.Wolfe, K.W.Hughes, Kudzma & D.Arora	RET 346-6	Copper Belt Province, Zambia	HQ539736
	A. congolensis	HLA0173	Africa	MK908833
	A. cf. *congolensis*	KM 17	Dja Biosphere Reserve, Cameroon	MT446292
	A. flavoconia G.FAtk.	BW_PH22	Massachusetts, USA	HQ539693
	A. karea G.S.Ridl.	JAC13435	New Zealand	MT862273
	A. luteolovelata D.A.Reid	PSC2187	SA	HQ539706
	A. luteofusca (Cleland & E.-J.Gilbert) E.-J. Gilbert	PSC1093b	SA	HQ539705
	A. marinae	PERTH 09535985	Shire of Dandaragan, WA	**OQ344669**

Section	***Amanita*** **spp.**	**Voucher number**	**Location**	**nuLSU**
	A. nothofagi G.Stev.	CS AK400	New Zealand	MT862267
	A. orsonii Ash.Kumar & T.N.Lakh.	RET 717-8	Uttarakhand, India	KX270345
	A. sp. 'Bealey'	PDD95341	New Zealand	MT862259
	A. sp. 'ostendemihi'	RET 605-3	Texas, USA	MN755854
	A. sp. 'ostendemihi'	RET 808-10	Texas, USA	MN755855
	A. sepiacea S.Imai	ASIS26393	Korea	KU139444
	A. submaculata Peck	RET 825-5	Missouri, USA	OP013101
	A. submaculata	RET 531-6	Indiana, USA	OP048958
	A. submaculata	RET 531-7	Indiana, USA	OP048959
Amanita	*A. subglobosa* ZhuL.Yang (outgroup)	HKAS58837	China	JN941152

Table 2. Voucher information and GenBank accession numbers for some species from sect. *Validae*. Newly published sequences are shown in bold. ITS, nuclear ribosomal internal transcribed spacer; *tef-1*, translation elongation factor 1-alpha; WA, Western Australia.

Amanita **spp.**	**Voucher number**	**Location**	**GenBank numbers**	
			ITS	**tef-1**
A. citrinoannulata Y.Y.Cui, Q.Cai & ZhuL. Yang	HKAS67956	Yunnan, China		MH508738
A. citrinoindusiata ZhuL.Yang, Y.Y.Cui & Q.Cai	HKAS58874	Yunnan, China		MH508746
A. citrinoindusiata	HKAS58886	Yunnan, China		MH508748
A. citrinoindusiata	HKAS58884	Yunnan, China		MH508747
A. citrinoindusiata	HKAS100522	Yunnan, China		MH508744
A. flavoconia	RET 480-5	New York state, USA		MH508789
A. karea	JAC13435	New Zealand		MT977112
A. marinae	PERTH 09535985	Shire of Dandaragan, WA	**OQ310901–OQ310905**	**OQ332414**
A. nothofagi	CS AK400	New Zealand		MT977106
A. orsonii	HKAS79670	Yunnan, China		MH508952
A. rubescens Pers.	HKAS101398	France		MH509038
A. sepiacea S.Imai	HKAS68336	Yunnan, China		MH509073
A. sepiacea	HKAS83643	Yunnan, China		MH509084
A. sepiacea	HKAS57371	Yunnan, China		MH509072
A. sepiacea	HKAS74750	Yunnan, China		MH509081
A. sepiacea	Li70805-48	Yunnan, China		MN657475
A. sepiacea	Voucher 38	China	MW192488	
A. sp. 'Bealey'	PDD95341	New Zealand	MT863752	MT977099
A. spissa (Fr.) P.Kumm.	HKAS100533	France		MH509113
A. djarilmari (outgroup)	PERTH 08776067	Shire of Cuballing, WA		MF000750

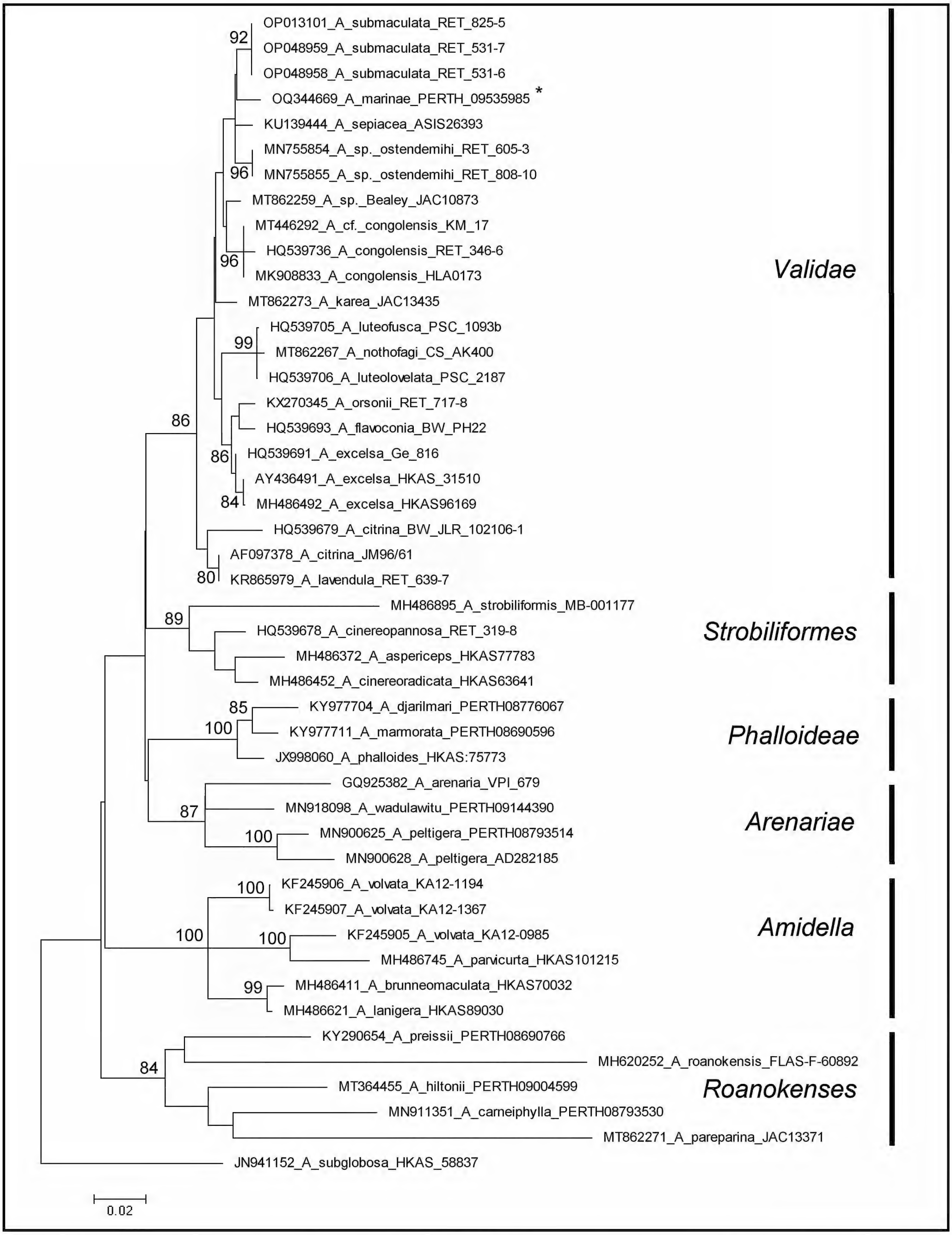
OP013101_A_submaculata_RET_825-5
92
OP048959_A_submaculata_RET_531-7
OP048958_A_submaculata_RET_531-6
OQ344669_A_marinae_PERTH_09535985 *
KU139444_A_sepiacea_ASIS26393
MN755854_A_sp._ostendemihi_RET_605-3
96
MN755855_A_sp._ostendemihi_RET_808-10
MT862259_A_sp._Bealey_JAC10873
MT446292_A_cf._congolensis_KM_17
HQ539736_A_congolensis_RET_346-6
96
MK908833_A_congolensis_HLA0173
MT862273_A_karea_JAC13435
HQ539705_A_luteofusca_PSC_1093b
99
MT862267_A_nothofagi_CS_AK400
HQ539706_A_luteolovelata_PSC_2187
KX270345_A_orsonii_RET_717-8
86
HQ539693_A_flavoconia_BW_PH22
86
HQ539691_A_excelsa_Ge_816
AY436491_A_excelsa_HKAS_31510
84
MH486492_A_excelsa_HKAS96169
HQ539679_A_citrina_BW_JLR_102106-1
AF097378_A_citrina_JM96/61
80
KR865979_A_lavendula_RET_639-7
Validae
MH486895_A_strobiliformis_MB-001177
89
HQ539678_A_cinereopannosa_RET_319-8
Strobiliformes
MH486372_A_aspericeps_HKAS77783
MH486452_A_cinereoradicata_HKAS63641
85
KY977704_A_djarilmari_PERTH08776067
100
KY977711_A_marmorata_PERTH08690596
Phalloideae
JX998060_A_phalloides_HKAS:75773
GQ925382_A_arenaria_VPI_679
87
MN918098_A_wadulawitu_PERTH09144390
100
MN900625_A_peltigera_PERTH08793514
Arenariae
MN900628_A_peltigera_AD282185
100
KF245906_A_volvata_KA12-1194
KF245907_A_volvata_KA12-1367
100
100
KF245905_A_volvata_KA12-0985
Amidella
MH486745_A_parvicurta_HKAS101215
99
MH486411_A_brunneomaculata_HKAS70032
MH486621_A_lanigera_HKAS89030
KY290654_A_preissii_PERTH08690766
84
MH620252_A_roanokensis_FLAS-F-60892
MT364455_A_hiltonii_PERTH09004599
Roanokenses
MN911351_A_carneiphylla_PERTH08793530
MT862271_A_pareparina_JAC13371
JN941152_A_subglobosa_HKAS_58837
0.02

Figure 1. Maximum likelihood phylogenetic tree based on nuLSU (nuclear large subunit rRNA) sequences (820 base pair positions), showing the position of *Amanita marinae* within subgenus *Amanitina*. The tree is rooted with *A. subglobosa* (subgen. *Amanita* sect. *Amanita*). Each section is listed on the right. The new species is indicated by *. Maximum likelihood bootstrap values greater than 80% are shown on the branches. The branch lengths are drawn to scale with branch lengths measured in the number of substitutions per site.

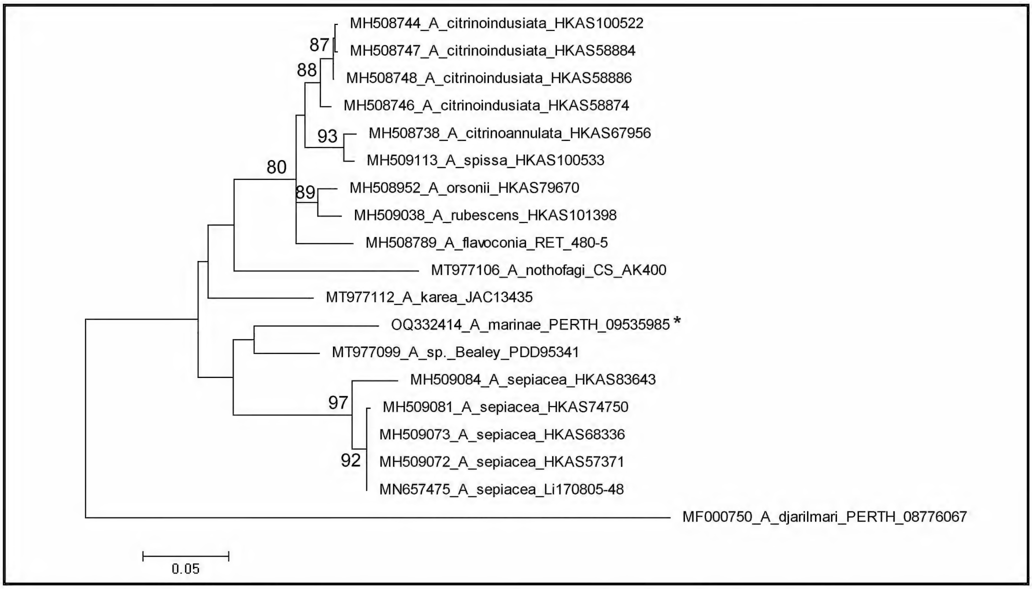
MH508744_A_citrinoindusiata_HKAS100522
87
MH508747_A_citrinoindusiata_HKAS58884
88
MH508748_A_citrinoindusiata_HKAS58886
MH508746_A_citrinoindusiata_HKAS58874
93
MH508738_A_citrinoannulata_HKAS67956
MH509113_A_spissa_HKAS100533
80
89
MH508952_A_orsonii_HKAS79670
MH509038_A_rubescens_HKAS101398
MH508789_A_flavoconia_RET_480-5
MT977106_A_nothofagi_CS_AK400
MT977112_A_karea_JAC13435
OQ332414_A_marinae_PERTH_09535985 *
MT977099_A_sp._Bealey_PDD95341
MH509084_A_sepiacea_HKAS83643
97
MH509081_A_sepiacea_HKAS74750
MH509073_A_sepiacea_HKAS68336
92
MH509072_A_sepiacea_HKAS57371
MN657475_A_sepiacea_Li170805-48
MF000750_A_djarilmari_PERTH_08776067
0.05

Figure 2. Maximum likelihood phylogenetic tree based on *tef-1* (translation elongation factor 1-alpha) sequences (468 base pair positions), showing the position of *Amanita marinae* within sect. *Validae*. The tree is rooted with *Amanita djarilmari* (sect. *Phalloideae*). The new species is indicated by *. Maximum likelihood bootstrap values greater than 80% are shown on the branches. The branch lengths are drawn to scale with branch lengths measured in the number of substitutions per site.

Table 3. Percentage difference between ITS clones from *A. marinae* and sequences of *A.* sp. 'Bealey' and *A. sepiacea.* The ITS region is 583–608 base pairs long.

Collection	No. of clones	*A. marinae* PERTH 09535985, OQ310901–OQ310905	*A.* sp. 'Bealey' PDD95341, MT863752
A. marinae PERTH 09535985, OQ310901–OQ310905	5	0.2–0.7	
A. sp. 'Bealey' PDD95341, MT863752	1	5.7–5.9	
A. sepiacea voucher 38, MW192488	1	6.1–6.4	4.6

Taxonomy

Amanita marinae E.M.Davison & Giustiniano, *sp. nov.*

Type: Lesueur National Park, Western Australia [precise locality withheld for conservation reasons], 18 May 2013, *E.M. Davison & P.J.N Davison* EMD 14-2013 (*holo*: PERTH 09535985). [MB847453]

Pileus 39–85 mm wide, white to ivory white (B) to pale vinaceous buff (3A2–5B2), without surface staining or bruising, initially convex becoming plane with depressed centre and decurved margin; margin non-striate, not or slightly appendiculate; context to 7 mm thick at the top of the stipe. *Universal veil on pileus* adnate, felted, initially crustose breaking into flat patches and soft warts over centre of disc, white, surface becoming pale vinaceous buff (5B2). *Lamellae* to 10 mm broad, adnate to free, close to subcrowded, white to ivory white (B), margin concolorous, slightly fimbriate; *lamellulae* frequent, in several lengths, truncate to subtruncate to subattenuate to attenuate. *Stipe* 14–57 × 13–21 mm, narrowing upwards or cylindric, white, surface smooth or floccose below partial veil. *Partial veil* superior or median, descendent, flaring, membranous, striate, persistent or fugacious, white. *Bulb* 18–40 × 17–28 mm, initially turbinate becoming fusiform to rooting. *Remains of universal veil* slight rim at top of bulb disappearing with age, white. *Pileus and stipe context* white to ivory white (B), becoming very pale vinaceous buff (pale 5B2) in bulb, and pale brown where damaged by insects; stipe solid becoming hollow. *Smell* none to slightly peppery to unpleasant with age. *Spore deposit* white to ivory white (B). (Figure 3)

Basidiospores [180/9/5] (8–)9–12(–13) × (5–)5.5–7(–8) µm (**L** = 9.6–11.2 µm; **L′** 10.5 µm; **W** = 5.9–6.6 µm; **W′** 6.4 µm), Q = (1.29–)1.42–1.92(–2.17) (**Q** = 1.48–1.79; **Q′** 1.65), elongate, occasionally ellipsoid, colourless, thin walled, smooth, amyloid; contents monogutulate or granular; apiculus sublateral, cylindrical or tapered, *c.* 1–1.5 × 1–2 µm, truncate or rounded. *Pileipellis* to 300 µm thick in old specimens, with a colourless gelatinised suprapellis to 150 µm thick and pale yellow subpellis, consisting of filamentous hyphae and frequent vascular hyphae (inflated cells not observed); filamentous hyphae 3–8 µm wide with widest constricted at septa, thick-walled, colourless, gelatinising, radially orientated with some interweaving; vascular hyphae 2–10 µm wide, occasionally branched, yellowish brown. *Pileus context* consisting of frequent filamentous hyphae, dominant inflated cells and very infrequent vascular hyphae; filamentous hyphae 3–20 µm wide, with widest hyphae constricted at septa, thin-walled, colourless; inflated cells to 240 × 45 µm, thin-walled, ventricose or clavate or ovoid, terminal, colourless; vascular hyphae 3–7 µm wide, pale yellow. *Lamella trama* bilateral, divergent. *Central stratum* to 30 µm wide, consisting of filamentous hyphae and very infrequent vascular hyphae (inflated cells not observed); filamentous hyphae 3–10 µm wide, thin walled, colourless; vascular hyphae 4 µm wide, pale yellow. *Subhymenial base* with angle of divergence 25–40° from central stratum, with filamentous hyphae following broad curve to subhymenium, consisting of dominant filamentous hyphae, infrequent inflated cells and very infrequent vascular hyphae; filamentous hyphae 3–17 µm wide, widest close to subhymenium and constricted at septa, frequently branched, thin walled, colourless; inflated cells to 40 × 15 µm when clavate or to 60 × 20 µm when ventricose or to 40 × 20 µm when ovoid, terminal, colourless; vascular hyphae 2–8 µm wide, some sinuous, pale yellow. *Subhymenium* with basidia arising terminally from terminal segments to 15 µm wide. *Lamella edge tissue* sterile, with inflated cells frequent, to 40 × 20 µm when pyriform or to 30 × 15 µm when ovoid or to 25 × 10 µm when cylindric, colourless. *Basidia* [90/5/5] (35–)38–58(–65) × (8–)9–12 µm, thin walled, colourless, *c.* 78% 4-spored, *c.* 19% 3-spored, *c.* 3% 2-spored; sterigmata to 7 × 2 µm. *Universal veil on pileus* not layered, elements with no dominant or somewhat anticlinal orientation, consisting of dominant to frequent filamentous hyphae and frequent to dominant inflated cells and infrequent vascular hyphae; filamentous hyphae 3–12 µm wide, colourless or some superficial hyphae with brown contents, gelatinising; inflated cells to 65 × 65 µm when spherical or to 75 × 65 µm when ovoid or to 60 × 35 µm when pyriform or to 55 × 25 µm when clavate, terminal or occasionally in chains of 2, colourless or pale brown, gelatinising; vascular hyphae 3–9 µm wide, pale yellow or pale brownish yellow. *Universal veil at stipe base* disorganised, consisting of frequent or dominant filamentous hyphae and dominant or frequent inflated cells and frequent to very infrequent vascular hyphae; filamentous hyphae 3–10 µm wide, some with thickened walls, colourless or brown, gelatinising; inflated cells to 55 × 55 µm when spherical or to 60 × 35 µm when ovoid or to 50 × 45 µm when pyriform or to 55 × 15 µm when clavate, terminal or occasionally in chains of 2, colourless or brown; vascular hyphae 3–8 µm wide, colourless or pale yellow or pale brownish yellow. *Stipe context* longitudinally acrophysalidic, consisting of frequent filamentous hyphae, dominant acrophysalides and very infrequent to frequent vascular hyphae; filamentous hyphae 3–10 µm wide, colourless; acrophysalides to 300 × 40 µm when

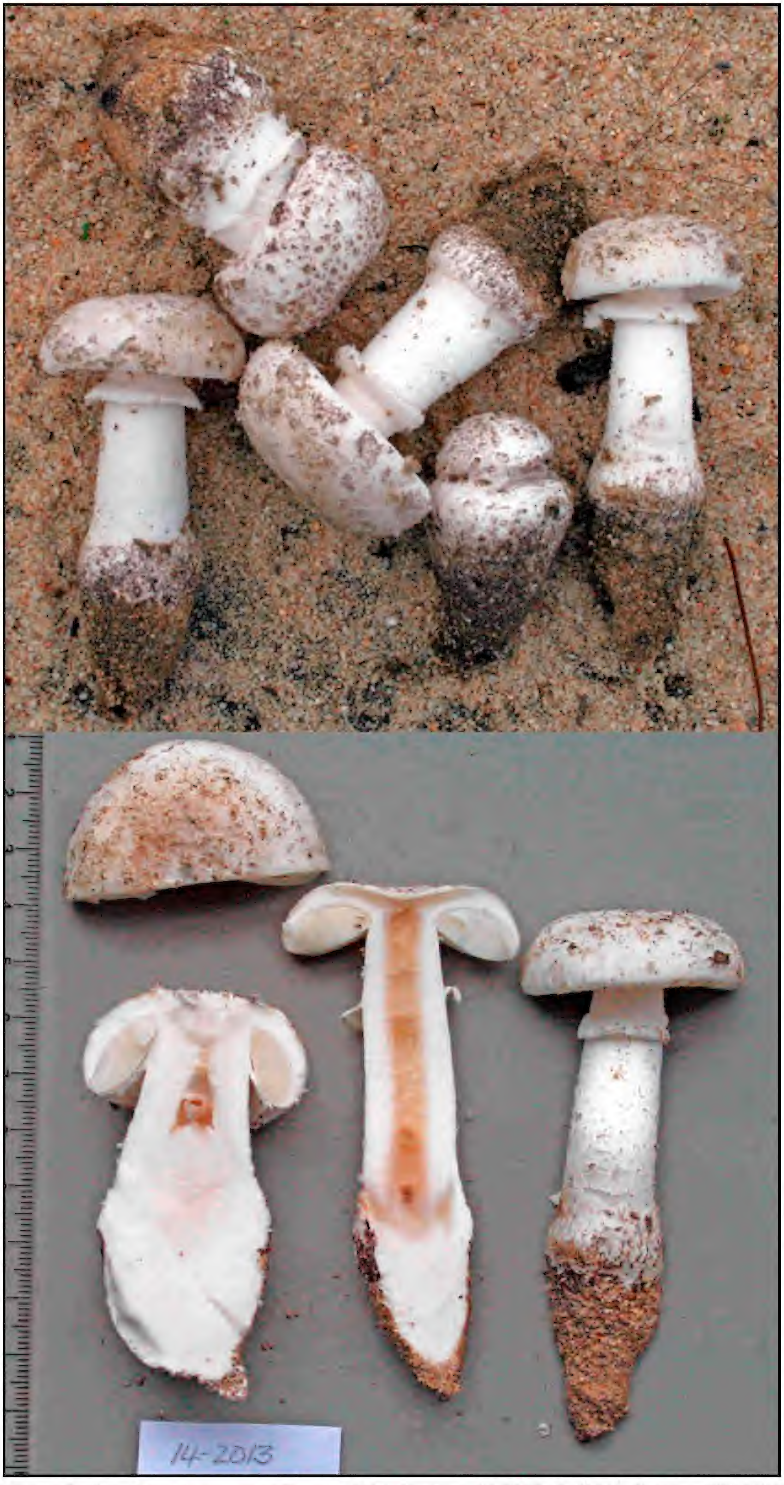

Figure 3. *Amanita marinae* basidiomes. *E.M. Davison* 14-2013 *& P.J.N. Davison* (PERTH 09535985). Photographs E.M. Davison.

clavate or to 250 × 35 µm when cylindric, terminal, colourless, gelatinising; vascular hyphae 2–11 µm wide, occasionally branched, pale yellow or pale yellowish brown. *Partial veil* layered. Superficial layer of partial veil consisting of filamentous hyphae with radial orientation (inflated cells not seen) and frequent vascular hyphae; filamentous hyphae 2–8 µm wide, slightly thickened walls, colourless, closely packed; vascular hyphae 2–5 µm wide, occasionally branched, pale yellowish brown. Central layer of partial veil consisting of frequent filamentous hyphae and dominant inflated cells (vascular hyphae not seen) with radial orientation; filamentous hyphae 2–8 µm wide, slightly thickened walls, colourless; inflated cells to 70 × 30 µm when ellipsoidal or up to 50 × 25 µm when ovoid, terminal, colourless. *Clamp connections* not observed. (Figure 4)

Diagnostic features. Basidiomata are small to medium. The pileus is white to ivory to pale vinaceous buff with a slightly appendiculate margin which disappears with age. It is initially covered with a white to pale vinaceous buff, felted universal veil which breaks up into patches and soft warts. The lamellae are white to ivory. The stipe is white, with a basal bulb which is initially turbinate and becomes fusiform to rooting with age. The partial veil is white, flaring and membranous, it may disappear with age. The universal veil at the top of the bulb forms only a slight, white ridge which disappears with age. There is no distinctive smell when young; when old the basidiomata smell unpleasant. The spores are amyloid and elongate. The universal veil tissue has no dominant orientation and is composed of an approximately equal mix of filamentous hyphae and terminal inflated cells which are mainly spherical and ovoid. Clamp connections are absent.

Other specimens examined. WESTERN AUSTRALIA: [precise localities withheld for conservation reasons] shire of Dandaragan, 7 June 2010, *E.M. Davison & P.J.N. Davison* EMD 16-2010 (PERTH 09535845); 7 June 2010, *E.M. Davison & P.J.N. Davison* EMD 17-2010 (PERTH 09535802); 18 May 2013, *E.M. Davison & P.J.N. Davison* EMD 16-2013 (PERTH 09535942); 18 May 2013, *E.M. Davison & P.J.N. Davison* EMD 17-2013 (PERTH 09535896).

Phenology. Basidiomes occur from May to June.

Distribution and habitat. Occurs singly or gregariously in sand over limestone or over loamy soil. In Kwongan vegetation; nearby plants include *Acacia* sp., *Banksia prionotes*, *Calothamnus* sp., *Eucalyptus todtiana* and *Hypocalymma xanthopetalum*. Occurs on the Geraldton Sandplain (GES) and Swan Coastal Plain (SWA) IBRA subregions (Department of Climate Change, Energy, the Environment and Water 2020).

Conservation status. To be listed as Priority Two under Conservation Codes for Western Australian Flora (Tanya Llorens, pers. comm.).

Etymology. The epithet honours Marina Wallace, whose team at Fiona Stanley Hospital saved EMD's life.

Notes. The phylogenetic analysis of nuLSU sequences (Figure 1) shows *A. marinae* is a member of sect. *Validae*, although its affinities within this section are not clear. Analysis of nuLSU also suggests it is more closely related to the northern hemisphere species *A. submaculata* and *A. sepiacea*, not to the Gondwanan species *A. karea, A. luteofusca, A. luteolovelata, A. nothofagi* and *A.* sp. 'Bealey' (an undescribed New Zealand species which had been isolated from soil). Phylogenetic analysis of *tef-1* shows it clusters close to *A.* sp. 'Bealey', although with poor support (Figure 2), and BLAST matches using the ITS region also shows it is closer to *A.* sp. 'Bealey' than to *A. sepiacea.*

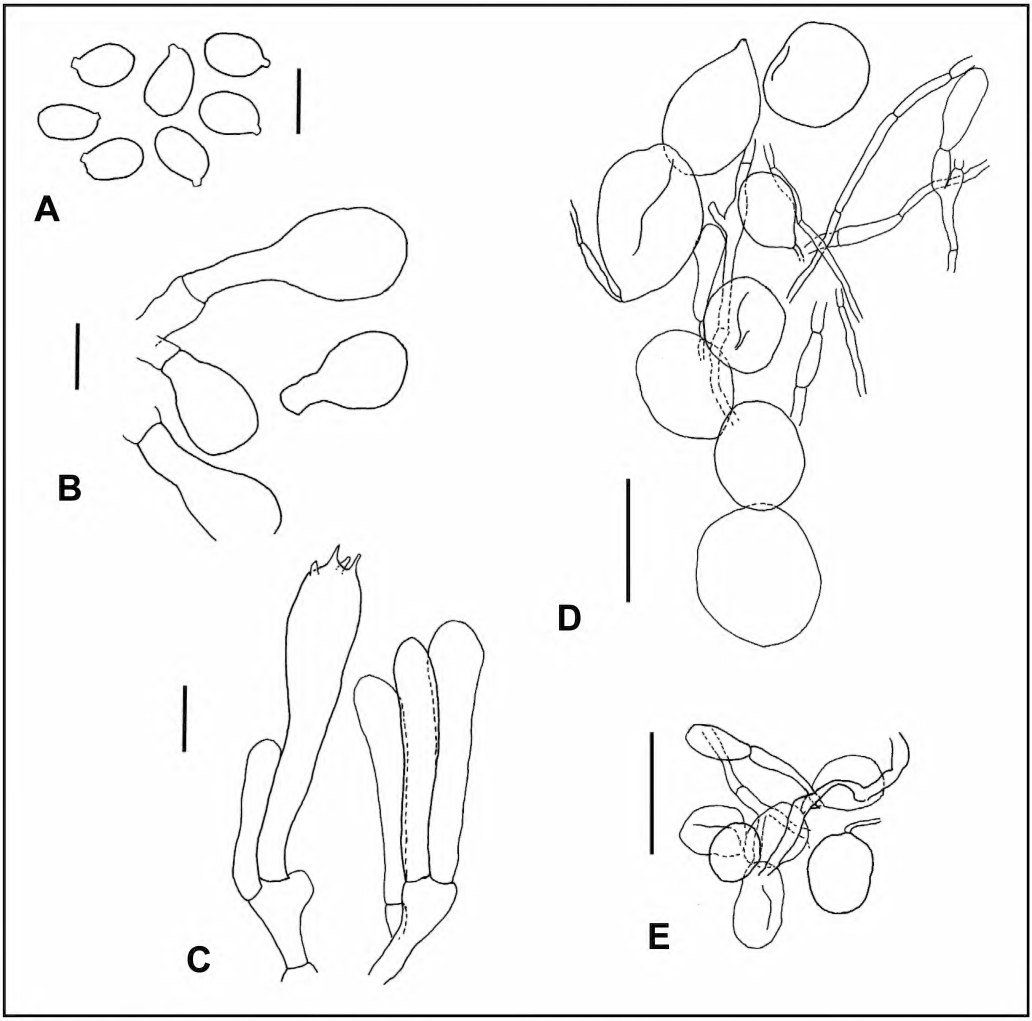

Figure 4. *Amanita marinae.* A – spores from spore print; B – marginal cells; C – basidia; D – universal veil on pileus, mid-radius, gentle squash; E – universal veil from stipe base, gentle squash. Scale bars = 10 µm (A–C); 50 µm (D–E). Images from *E.M. Davison* 14-2013 *& P.J.N. Davison* (PERTH 09535985).

Wood (1997) describes 16 species from eastern Australia that he considered to be members of sect. *Validae*, although following molecular studies some of these are no longer considered to be members of this section. Four of these (*A. basibulbosa* A.E.Wood, *A. cinerascens* A.E.Wood, *A. elongatospora* A.E.Wood and *A. griseoconia* D.A.Reid) differ from *A. marinae* because they have clamp connections. *Amanita marinae* differs from *A. flavella* (E.-J.Gilbert) E.-J.Gilbert & Cleland and *A. luteolovelata* because the basidiomes do not have orange or yellow colouring. It differs from *A. fuscobrunnea* A.E.Wood because it does not have conical brown warts on the pileus or brown scales, as in *A. fuscosquamosa* A.E.Wood. The spores of *A. marinae* are elongate (**Q** = 1.48–1.79), not broadly ellipsoidal as in *A. pallidogrisea* A.E.Wood (**Q** = 1.29–1.32) and *A. grisella* (E.-J.Gilbert) E.-J.Gilbert & Cleland (**Q** = 1.19–1.35), or subglobose as in *A. luteofusca* (Cleland & E.-J.Gilbert) E.-J.Gilbert (**Q** = 1.19–1.35). It differs from *A. griselloides* D.A.Reid and *A. griseovelata* D.A.Reid because the spores are elongate (**Q** = 1.48–1.79), not ellipsoidal (**Q** = 1.30–1.46 and **Q** = 1.37, respectively). The only species within

Wood's interpretation of sect. *Validae* with elongate spores is *A. sordidogrisea* A.E.Wood, and the spores of this species ((6.6–)7.5–9.0 × (4.2–)4.8–5.4 µm) are smaller than those of *A. marinae* ((8–)9–12(–13) × (5−)5.5–7(–8) µm). *Amanita marinae* differs from *A. peltigera* D.A.Reid and *A. grisea* Massee & Rodway because there is no distinct volval limb at the base of the stipe.

Miller (1992) described *A. basiorubra* O.K.Mill., a red-bruising species that he considered a member of sect. *Validae*. This differs from *A. marinae* in both pileus colour, brown compared with white or ivory white, spore size (7.6–9.0 × 5.5–6.7 µm, compared with (8–)9–12(–13) × (5−)5.5–7(–8) µm) and shape (**Q** = 1.39, compared with **Q** = 1.48–1.79).

Among the described species of Australian *Amanita* there are several that are small to medium and white or pale, with amyloid, elongate spores and which lack clamp connections. *Amanita marinae* does not develop yellow colouration and lacks the strong chemical smell of *A. preissii* (Fr.) Sacc., and the spores are shorter than those of *A. clelandii* Gilb. (*A. marinae*: **L** = 9.6–11.2 µm, *A. clelandii*: **L** = 9.0–16.0 µm (Reid 1980)). It differs from *A. lesueurii* E.M.Davison because the partial veil is superior, not inferior to median to superior, and the spores are elongate (**Q** = 1.48–1.79) not elongate to cylindric (**Q** = 1.90–2.26). On this basis, supported by phylogenetic separation, *A. marinae* is described as a new species.

Discussion

One of the aims of this work was to determine the degree of variability of the ITS region for *A. marinae*. Table 3 shows there is 0.2–0.7% variation between cloned haplotypes of *A. marinae*, which is comparable to the less than 2% divergence observed by Hughes *et al.* (2013) for other members of sect. *Validae*. This is far less than the ITS region base pair divergence we have observed in Australian members of sect. *Arenariae* and sect. *Roanokenses*, where base pair divergence between haplotypes from the same individual may vary between 0.0–8.1% and 0.5–8.0%, respectively (Davison *et al.* 2021, 2023). In view of the ITS variability in members of various sections of *Amanita*, we advocate species delimitation of *Amanita* taxa be based on multi-gene analyses.

Acknowledgements

This work was supported by Lotterywest Grant Application 421011392 and the Western Australian Naturalists' Club Gift Fund. We thank the staff of the Western Australian Herbarium for processing the collections. N.L. Bougher, T. May and B. Anderson are thanked for providing constructive comments on the manuscript.

References

Altschul, S.F., Gish, W., Miller, W., Myers, E.W. & Lipman, D.J. (1990). Basic local alignment search tool. *Journal of Molecular Biology* 215: 403–410.

Bas, C. (1969). Morphology and subdivision of *Amanita* and a monograph of its section *Lepidella*. *Persoonia* 5: 285–579.

Cui, Y.-Y., Cai, Q., Tang, L.-P., Liu, J.-W. & Yang, Z.L. (2018). The family Amanitaceae: molecular phylogeny, higher-rank taxonomy and the species in China. *Fungal Diversity* 91: 5–230.

Davison, E.M. (2011). *Amanita ochroterrea* and *Amanita bruneiphylla* (Basidiomycota), one species or two? *Nuytsia* 21: 177–184.

Davison, E.M. & Giustiniano, D. (2020). *Amanita hiltonii* (Amanitaceae), a common but frequently misidentified mushroom in southwestern Australia, and a reconsideration of *A. albifimbriata* and *A. brunneibulbosa*. *Muelleria* 39: 59–73.

Davison, E.M., Giustiniano, D., Barrett, M.D. & Syme, K. (2023). Four new species of *Amanita* section *Roanokenses* (Basidiomycota) from Western Australia. *Nuytsia* 34: 65–92.

Davison, E.M., Giustiniano, D., Bougher, N.L., McGurk, L.E. & Watkin, E.L.J. (2021). Additions to *Amanita* (Amanitaceae, Agaricales) section *Arenariae* from southwestern-Australia. *Australian Systematic Botany* 34: 541–569.

Davison, E.M., Giustiniano, D., Busetti, F., Gates, G.M. & Syme, K. (2017a). Death cap mushrooms from southern Australia: additions to *Amanita* (Amanitaceae, Agaricales) section *Phalloideae* Clade IX. *Australian Systematic Botany* 30: 371–389.

Davison, E.M., Giustiniano, D. & Haska, J.F. (2020). Clarification of the type locality of *Amanita peltigera* (Agaricales, Amanitaceae), phylogenetic placement within subgenus *Amanitina*, and an expanded description. *Swainsona* 33: 51–61.

Davison, E.M., Giustiniano, D., McGurk, L.E., Syme, K. & Robinson, R.M. (2015). *Amanita drummondii* and *A. quenda* (Basidiomycota), two new species from Western Australia, and an expanded description of *A. walpolei*. *Nuytsia* 25: 1–13.

Davison, E.M., Giustiniano, D., McGurk, L.E., Watkin, E.L.J. & Bougher, N.L. (2017b). Neotypification and redescription of *Amanita preissii* (Basidiomycota), and a reconsideration of the status of *A. griseibrunnea*. *Nuytsia* 28: 193–204.

Davison, E.M., McGurk, L.E., Bougher, N.L., Syme, K. & Watkin, E.L.J. (2013). *Amanita lesueurii* and *A. wadjukiorum* (Basidiomycota), two new species from Western Australia, and an expanded description of *A. fibrillopes*. *Nuytsia* 23: 589–606.

Department of Climate Change, Energy, the Environment and Water. (2020). Interim Biogeographic Regionalisation for Australia v. 7 (IBRA). Canberra, ACT. https://www.dcceew.gov.au/environment/land/nrs/science/ibra/australias-bioregions-maps [accessed 7 Mar. 2023].

Edgar, R.C. (2004). MUSCLE: Multisequence alignment with high accuracy and high throughput. *Nucleic Acids Research* 32: 1792–1797.

Grgurinovic, C.A. (1997). *Larger Fungi of South Australia.* (The Botanic Gardens of Adelaide and State Herbarium: Adelaide, SA, Australia.)

Hughes, K.W., Petersen, R.H., Lodge, D.J., Bergemann, S.E., Baumgartner, K., Tulloss, R.E., Lickey, E. & Cifuentes, J. (2013). Evolutionary consequences of putative intra- and interspecific hybridization in agaric fungi. *Mycologia* 105: 1577–1594.

Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitution through comparative studies of nucleotide sequences. *Journal of Molecular Evolution* 16: 111–120.

Kornerup, A. & Wanscher, J.H. (1983). *Methuen Handbook of Colour.* 3rd edn. (Methuen: London.)

McGurk, L.E., Giustiniano, D., Davison, E.M. & Watkin, E.J. (2016). *Amanita wadulawitu* (Basidiomycota), a new species from Western Australia, and an expanded description of *A. kalamundae. Nuytsia* 27: 21–30.

Miller, O.K. Jr. (1991). New species of *Amanita* from Western Australia. *Canadian Journal of Botany* 69: 2692–2703.

Miller, O.K. Jr. (1992). Three new species of *Amanita* from Western Australia. *Mycologia* 84: 679–686.

Reid, D.A. (1980). A monograph of the Australian species of *Amanita* Pers. ex Hook. (Fungi). *Australian Journal of Botany; Supplementary Series* No. 8: 1–97.

Royal Botanic Garden, Edinburgh (1969). *Flora of British fungi: colours identification chart*. (Her Majesty's Stationery Office: Edinburgh.)

Schoch, C.L., Seifert, K.A., Huhndorf, S., Robert, V., Spouge, J.L., Levesque, C.A., Chen, W. & Fungal Barcoding Consortium (2012). Nuclear ribosomal internal transcribed spacer (ITS) region, a universal DNA barcode marker for Fungi. *Proceedings of the National Academy of Sciences* 109: 6241–6246.

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. & Kumar, S. (2011). Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution* 28: 2731–2740.

Tamura, K. & Nei, M. (1993). Estimation of the number of nucleotides substitutions in the control region of mitochondrial DNA in humans and chimpanzees. *Molecular Biology and Evolution* 9: 512–526.

Tulloss, R.E. (2000). *Notes on methodology for study of Amanita (Agaricales).* http://www.amanitaceae.org/content/uploaded/pdf/methodsb.pdf [accessed 11 Aug. 2016].

Wood, A.E. (1997). Studies in the genus *Amanita* (Agaricales) in Australia. *Australian Systematic Botany* 10: 723–854.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01053

Nuytsia 34: 125–137
Published online 27 April 2023

Taxonomic resolution of infraspecific taxa in *Lambertia orbifolia* (Proteaceae) using molecular and morphological evidence

Juliet A. Wege[1,3], Leonie T. Monks[1], Andrew D. Webb[2], Rachel M. Binks[1] and David J. Coates[1]

[1]Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2]South West Region, Parks and Wildlife Service,
Department of Biodiversity, Conservation and Attractions,
P.O. Box 1693, Bunbury, Western Australia 6231
[3]Corresponding author, email: Juliet.Wege@dbca.wa.gov.au

Abstract

Wege, J.A., Monks, L.T., Webb, A.D., Binks, R.M. & Coates, D.J. Taxonomic resolution of infraspecific taxa in *Lambertia orbifolia* (Proteaceae) using molecular and morphological evidence. *Nuytsia* 34: 125–137 (2023). The taxonomy of three informally-named, conservation-listed subspecies of *Lambertia orbifolia* C.A.Gardner was assessed using genotypic data generated from microsatellites in concert with morphological information. They were found to warrant formal taxonomic recognition and individualised conservation management. *Lambertia orbifolia* subsp. *vespera* A.D.Webb, L.Monks & Wege, an Endangered taxon from the Scott River Plains, and *L. orbifolia* subsp. *pecuniosa* A.D.Webb, L.Monks & Wege, a recently discovered and apparently rare taxon from south-west of Bowelling, are newly described and comparative data are provided for *L. orbifolia* subsp. *orbifolia*, a Critically Endangered taxon found near Narrikup. A revised description of *L. orbifolia* is also provided.

Introduction

Lambertia orbifolia C.A.Gardner (Proteaceae) was described from a single specimen collected in 1962 by Alfred J. Grey from near Albany in Western Australia (Gardner 1964). Its circumscription was subsequently expanded to include a population on the Scott River Plain near Augusta, discovered by Robert D. Royce in 1945, and one from near Narrikup, discovered by Ken R. Newbey in 1964 (George 1984; Hnatiuk 1995; Western Australian Herbarium 1998–). It was listed as Declared Rare Flora in November 1980 under the *Western Australian Wildlife Conservation Act 1950* (Luu & English 2004), at which time only two extant regional population groups (Narrikup and Augusta) were known.

Genetic variation across the range of *L. orbifolia* was investigated in the late 1990s in response to ongoing declines in habitat quality and plant number, and persistent threats to its survival including land clearing, dieback disease caused by *Phytophthora cinnamomi*, aerial canker (*Cryptodiaporthe* sp., *Diplodina* sp.), weed invasion and mining-related activities. Analyses of isozyme, chloroplast DNA and nuclear ribosomal DNA variation revealed a very high level of genetic divergence between the two regional population centres that pointed to two distinct, historically isolated evolutionary

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

lineages (Byrne *et al.* 1999; Coates & Hamley 1999). Based on these data, populations from the Augusta region were added to Western Australia's vascular plant census in September 1999 under the informal phrase name *L. orbifolia* subsp. Scott River Plains (L.W. Sage 684) and the taxon listed as Declared Rare Flora with a ranking of Endangered (Atkins 1999; Luu & English 2004). The ranking of the typical subspecies was simultaneously upgraded to Critically Endangered (Phillimore & Brown 2002) under the name *L. orbifolia* subsp. *orbifolia* ms (Western Australian Herbarium 1998–). There are currently five known natural populations and one translocation of subsp. Scott River Plains in the Augusta region and four natural populations and two translocations of subsp. *orbifolia* ms in the Narrikup region, with these regions being some 250 km apart. More recent genetic assessment using microsatellite markers has confirmed the genetic distinction of these disjunct regional groupings and supports their continued recognition as subspecies (Monks *et al.* 2021).

A formal taxonomic assessment of subsp. Scott River Plains has never been completed. Initially considered morphologically indistinguishable from the typical form (Hnatiuk 1995; Byrne *et al.* 1999), it was subsequently noted as having longer inflorescence bracts and flowers with a longer style (Phillimore & Brown 2002; Luu & English 2004), although comparative measurements were not documented. The recent discovery of two populations near Bowelling that cannot be confidently assigned to either subspecies brings a renewed sense of urgency to resolving this long-standing taxonomic issue. These new populations, which occur nearby to one another but some 100 km north of the species' previously known range, have been assigned the phrase name *L. orbifolia* subsp. Bowelling (A. Webb AW 09107) (Western Australian Herbarium 1998–).

Here we assess morphological variation across the informally recognised subspecies of *L. orbifolia* and add genetic data for subsp. Bowelling to the Monks *et al.* (2021) dataset, with a view to using both lines of evidence to resolve their taxonomic status and further inform the conservation and management of all subspecies.

Methods

Morphological and ecological data were obtained through the examination of specimens at the Western Australian Herbarium (PERTH), field observations and an assessment of available literature and images.

Leaf material for genetic analysis was collected from 24 widely spaced individuals from the population of subsp. Bowelling that was discovered in 2020 (the second population was found after these analyses were completed). Extraction of DNA and genotyping using microsatellite markers was undertaken following the methods outlined in Monks *et al.* (2021) except for the removal of two loci (Lo 22 and Lo 46) due to scoring inconsistencies. The resulting genotypic data was added to the data previously generated from the natural populations of subsp. *orbifolia* ms and subsp. Scott River Plains (Monks *et al.* 2021). No loci showed evidence of null alleles across all populations (Monks *et al.* 2021), therefore the combined dataset was considered suitable for re-analysis across the 11 microsatellite loci to assess genetic relationships among the three regional population groups using genetic diversity measures (allelic richness N_{AR}, observed heterozygosity H_O and expected heterozygosity H_E, and the inbreeding coefficient F_{IS}), differentiation measures (F_{ST} and D_{ST}), principal coordinates analysis (PCoA) and STRUCTURE analysis. Methodologies and running parameters for these analyses were identical to those used previously (see Monks *et al.* 2021), except that the hierarchical STRUCTURE analyses were run with a higher upper K value (in each case, the total number of populations plus one) to accommodate the possibility that the additional population may represent an additional cluster.

Population vouchers for the genetic study are as follows: subsp. *orbifolia* ms – ORB-J (PERTH

08599971), ORB-SS (PERTH 08575479), ORB-ES (PERTH 08575509), ORB-S (PERTH 08575487), ORB-WN (PERTH 05569508); subsp. Bowelling – BOW (PERTH 09279075); subsp. Scott River Plains – SRP-WD (PERTH 07464029); SRP-B (PERTH 04669126); SRP-D (PERTH 09444807); SRP-AS (PERTH 04135784).

Results and Discussion

The population of subsp. Bowelling showed similar levels of genetic diversity to populations of subsp. Scott River Plains and subsp. *orbifolia* ms (Table 1), with subsp. Scott River Plains showing higher values for N_{AR}, H_O, H_E and F_{IS} than subsp. *orbifolia* ms as per Monks *et al.* (2021). The population of subsp. Bowelling showed lower values for H_O and H_E and a higher value for F_{IS} than populations of the other two subspecies (Table 1), although none of these values were significantly different. Private alleles were found in nine loci for subsp. *orbifolia* ms, 10 loci for subsp. Scott River Plains and nine loci for subsp. Bowelling across the 11 microsatellite loci assessed.

There was significant genetic differentiation among the populations of *L. orbifolia*, with high overall values for genetic fixation and allelic differentiation ($F_{ST} = 0.395$; $D_{ST} = 0.587$) that were elevated from those in Monks *et al.* (2021) following the addition of the Bowelling population. Pairwise measures of F_{ST} among the subspecies were high (Table 2), with mean $F_{ST} = 0.294$ between populations of subsp. Scott River Plains and subsp. *orbifolia* ms, mean $F_{ST} = 0.261$ between subsp. Scott River Plains and subsp. Bowelling, and mean $F_{ST} = 0.351$ between subsp. *orbifolia* ms and subsp. Bowelling. Pairwise D_{ST} values showed the same relative patterns to the F_{ST} values, including higher differentiation in comparisons between regions than those within regions (Table 2).

The PCoA was consistent with Monks *et al.* (2021) in that the first axis (representing 35.4% of the total variation) separated individuals of subsp. Scott River Plains and subsp. *orbifolia* ms into two broad clusters and the second axis (18.7% of the variation) showed separation of the easternmost population of subsp. *orbifolia* ms (ORB-WN) from the remaining populations of that subspecies (Figure 1A). Individuals of subsp. Bowelling fell mid-way between the two clusters on the first axis (albeit with slightly closer affinity to subsp. Scott River Plains) but separated from both clusters on the second axis. The third axis explained a similar proportion of variation (17.72%) as the second axis and further separated the population of subsp. Bowelling from the subsp. Scott River Plains and subsp. *orbifolia* ms clusters, while the previously outlying ORB-WN population was more closely associated with the rest of the subsp. *orbifolia* ms cluster (Figure 1B).

STRUCTURE analysis results were largely consistent with that of Monks *et al.* (2021), identifying two major genetic groups to distinguish populations of subsp. *orbifolia* ms (Narrikup) from those of subsp. Scott River Plains (Augusta). The population of subsp. Bowelling grouped with the subsp. Scott River Plains cluster with no indication of admixture or ambiguity (Figure 2). Hierarchical analysis within each of these clusters detected further substructure. Within the subsp. *orbifolia* ms cluster, each population formed a separate subcluster as per Monks *et al.* (2021), while substructure within the subsp. Scott River Plains + subsp. Bowelling cluster clearly distinguished only the Bowelling population from the remaining populations. Further hierarchical assessment of the subsp. Scott River Plains subcluster identified the population structuring reported in Monks *et al.* (2021).

In addition to being genetically distinct, the three subspecies can be recognised morphologically using a combination of bract and indumentum features (detailed in the key below). Subsp. Scott River Plains can be diagnosed by its bracts, which have a glabrous or scarcely papillose outer surface (*cf.* densely hairy distally in the other two subspecies). The bracts are usually straight (the outermost

Table 1. Summary of sampling and mean (SE) genetic diversity measures for the three subspecies of *Lambertia orbifolia*. N_{POPS} = no. of populations sampled per region; N_{IND} = no. of individuals sampled per population; N_{AR} = allelic richness; H_{O} = observed heterozygosity; H_{E} = expected heterozygosity; F_{IS} = inbreeding coefficient.

Subspecies	N_{POPS}	N_{IND}	N_{AR}	H_{O}	H_{E}	F_{IS}
Scott River Plains	4	23.25 (0.28)	2.99 (0.34)	0.41 (0.03)	0.51 (0.05)	0.14 (0.03)
***orbifolia* ms**	5	22.40 (0.94)	2.47 (0.24)	0.36 (0.06)	0.42 (0.07)	0.11 (0.06)
Bowelling	1	23.64 (0.36)	2.61 (0.30)	0.31(0.07)	0.39 (0.07)	0.29 (0.07)

Table 2. Pairwise F_{ST} (below diagonal) and D_{ST} (above diagonal) for populations of *Lambertia orbifolia* subsp. Scott River Plains (SRP), subsp. Bowelling (BOW) and subsp. *orbifolia* ms (ORB). Population vouchers are listed in the methods.

	SRP-WD	SRP-B	SRP-D	SRP-AS	BOW	ORB-J	ORB-SS	ORB-ES	ORB-S	ORB-WN
SRP-WD	-	0.018	0.270	0.244	0.614	0.735	0.771	0.512	0.684	0.687
SRP-B	0.020	-	0.231	0.164	0.615	0.721	0.779	0.538	0.693	0.717
SRP-D	0.129	0.117	-	0.285	0.510	0.783	0.843	0.649	0.845	0.676
SRP-AS	0.102	0.076	0.157	-	0.619	0.648	0.813	0.593	0.756	0.701
BOW	0.238	0.251	0.284	0.271	-	0.733	0.698	0.546	0.863	0.776
ORB-J	0.361	0.355	0.476	0.336	0.423	-	0.404	0.383	0.460	0.624
ORB-SS	0.228	0.232	0.337	0.263	0.281	0.227	-	0.316	0.449	0.501
ORB-ES	0.154	0.166	0.264	0.191	0.220	0.222	0.113	-	0.366	0.539
ORB-S	0.234	0.243	0.378	0.285	0.375	0.283	0.175	0.149	-	0.622
ORB-WN	0.308	0.328	0.407	0.323	0.454	0.415	0.276	0.273	0.363	-

ones are sometimes weakly recurved) rather than consistently strongly recurved like those of subsp. *orbifolia* ms; the bracts of subsp. Bowelling are somewhat variable in this regard but usually resemble the typical subspecies. While there is a strong tendency for subsp. Scott River Plains to have longer inner bracts than the typical subspecies, there is a degree of overlap (18–28 mm long *cf.* 12–20 mm in subsp. *orbifolia* ms), with bract length becoming less taxonomically reliable when populations of subsp. Bowelling are considered (15–23 mm long).

Subsp. Bowelling differs from the other two subspecies in having young branchlets with an even indumentum of short, crispate hairs (*cf.* with both long, spreading hairs and short, crispate hairs). It also has shorter hairs on the outer surface of the perianth (mostly to 0.2 mm long but sometimes with sparse hairs to 0.5(–1.5) mm long *cf.* hairs (0.5–)1–3 mm long in the other two subspecies). The flowers of the three subspecies are otherwise comparable, with colour varying both among and within populations. Style length, which is difficult to accurately measure on pressed material, does not appear to be taxonomically informative as previously suggested (Luu & English 2004).

The presence of private alleles, high levels of genetic differentiation and strong population structuring across populations of subsp. *orbifolia* ms, subsp. Scott River Plains, and subsp. Bowelling indicate significant restrictions to gene flow among these geographically disjunct subspecies. The addition of the subsp. Bowelling population to the genetic analysis did not alter the divergent patterns seen between subsp. *orbifolia* ms and subsp. Scott River Plains as per Monks *et al.* (2021), which were

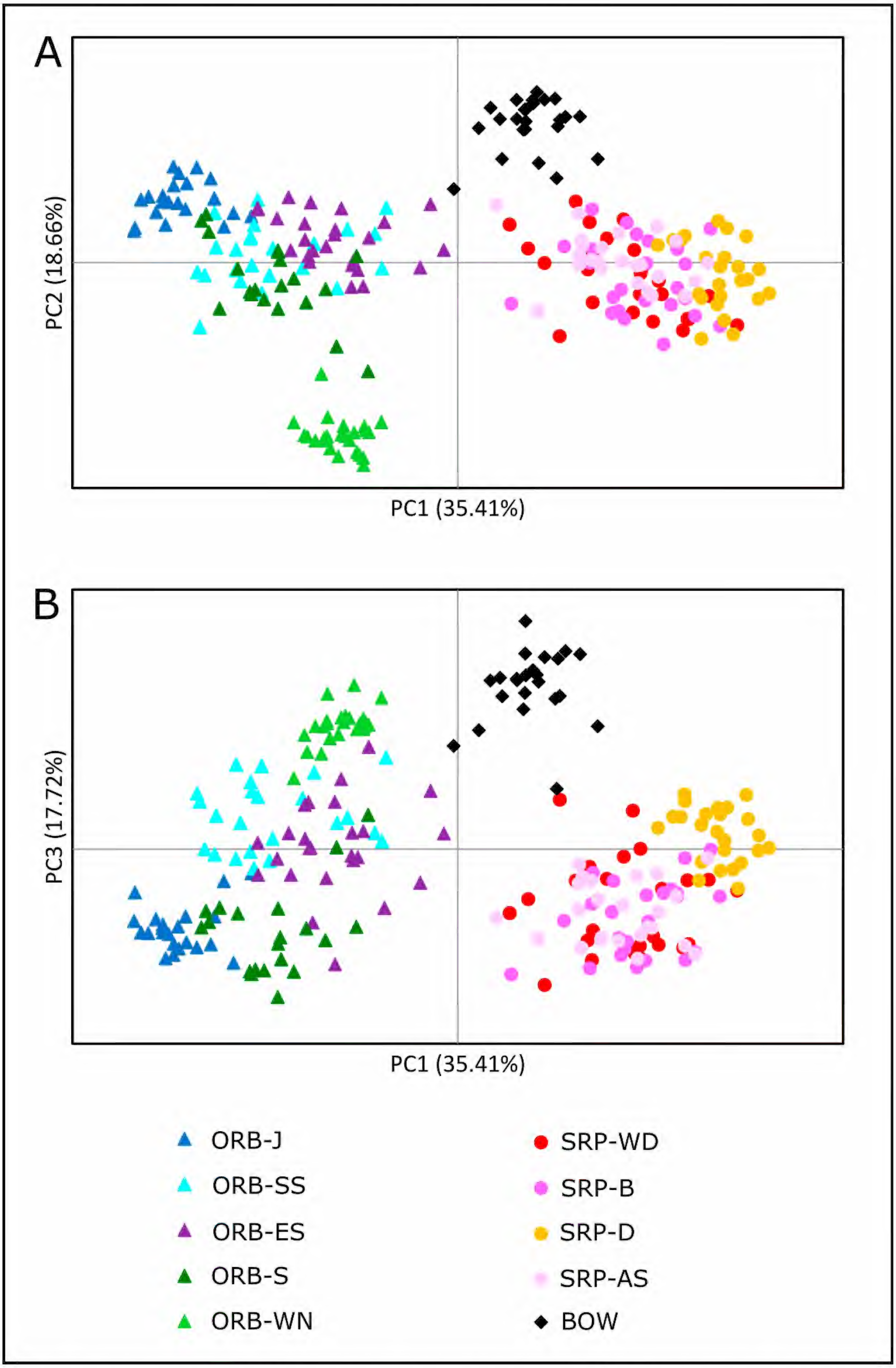

Figure 1. Principal coordinates analysis for individuals of *Lambertia orbifolia* sampled across 10 populations and three disjunct geographic regions: subsp. *orbifolia* ms (Narrikup) is represented by triangles, subsp. Scott River Plains (Augusta) by circles, and subsp. Bowelling by diamonds. A – principal coordinate (PC) axes 1 and 2; B – PC axes 1 and 3.

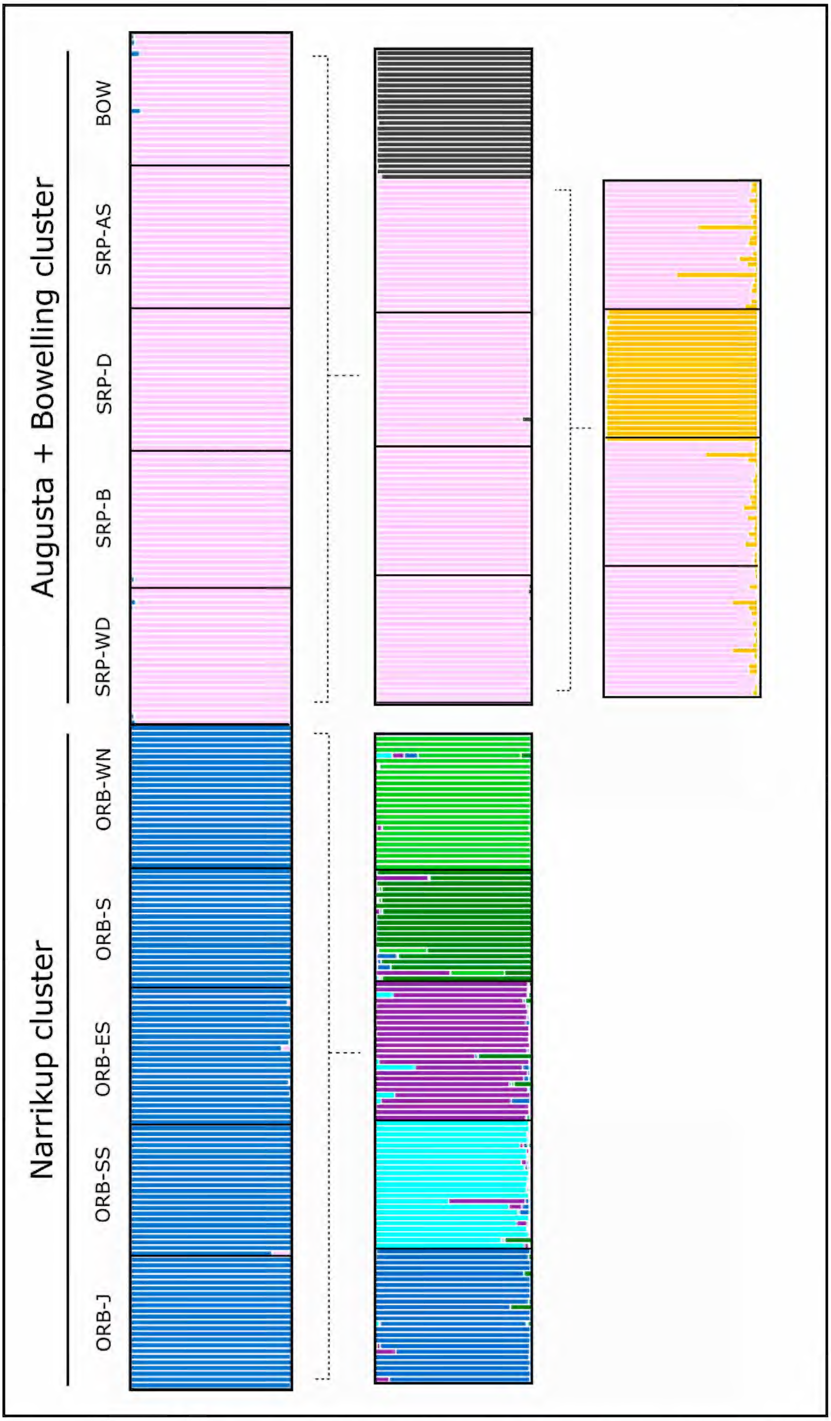

Figure 2. Upper tier – structure analysis for all sampled populations of *Lambertia orbifolia* showing two distinct genetic clusters (K = 2) comprising all populations of subsp. *orbifolia* ms (Narrikup cluster) and all populations of subsp. Scott River Plains and subsp. Bowelling (Augusta + Bowelling cluster). Middle tier – hierarchical analyses within the Narrikup (K=5) and Augusta + Bowelling (K = 2) clusters. Lower tier – further hierarchical analysis within the Augusta subcluster (K = 2).

also consistent with those found in older molecular studies (Byrne *et al.* 1999; Coates & Hamley 1999). While subsp. Bowelling shows a closer genetic affinity to subsp. Scott River Plains, its long-term geographic isolation is reflected in the hierarchical substructuring of this population as highly distinct from those of subsp. Scott River Plains. Coupled with morphological evidence, we consider these taxa to represent three independently functioning entities that warrant taxonomic recognition and individualised conservation management. A formal taxonomy is presented below.

Taxonomy

Lambertia orbifolia C.A.Gardner, *J. Roy. Soc. W. Australia* 47: 55 (1964). *Type*: Prope King River, King George's Sound, Western Australia, June 1962, *A.J. Gray s.n.* (*holo*: PERTH 01006576).

Single- or multi-stemmed *shrub* or *small tree* 2–6 m high, openly or densely branched, lignotuber apparently absent. *Branches* erect, spreading or arching, glabrescent; young branchlets usually with ± spreading, rusty brown, simple hairs *c.* 0.5–3 mm long over dense, rusty brown or white crispate or sometimes antrorse hairs *c.* 0.1–0.3(–0.5) mm long, more rarely with the longer hairs absent. *Leaves* opposite, shortly petiolate, coriaceous, with dense, crispate hairs on adaxial surface towards base of adaxial midrib and on petiole, hairs sometimes present on remaining adaxial (rarely abaxial) veins or margins (especially when young); petiole 1.5–5 mm long; lamina orbicular, elliptic or ovate, 10–50 mm long, 8–40 mm wide, flat or somewhat cupped, with prominent reticulate venation, margins entire; apex rounded to obtuse or ± subacute, sometimes apiculate; base cordate or rounded. *Conflorescence* terminal or on short, lateral shoots, 4–6-flowered. *Bracts* numerous, pale brown to dark red-brown, 1–25 mm long (inner bracts 10–25 mm long, outer bracts shorter), straight or with a weakly to strongly recurved tip; pubescent or tomentose on both surfaces and margins, densely so towards apex, becoming glabrous towards base, sometimes with hairs absent from abaxial (outer) surface (rarely completely glabrous). *Flowers* zygomorphic, facing outwards, suberect to spreading. *Perianth* red or orange-red with brownish or more rarely yellow limbs, *c.* 30–60 mm long, dilated about middle with limbs becoming tightly revolute, abaxial suture deepest; outer surface with simple, spreading, white or pale rusty brown hairs 0.2–3 mm long, sparse on tube, becoming denser distally; inner surface with scattered, thickened hairs *c.* 0.1–0.3 mm long. *Stamens* 4 (1 in each lobe of limb), shortly pedicellate, with an apical gland. *Ovary* densely brown- or white-pilose; style *c.* 3.5–5.5 mm long, glabrous distally, sparsely pilose towards base; stigma apically grooved, distal to slightly swollen pollen presenter. *Hypogynous glands* 4, free, glabrous. *Fruit* a follicle, splitting when seeds ripe, asymmetric, shortly beaked, 13–20 mm long, 5–11 mm diam., horns at distal end of suture scarcely developed or apparently absent; sides smooth, glabrescent. *Seeds* 1 or 2 per follicle, asymmetric in outline with one side ± straight and the other rounded and very narrowly winged, 8–12 mm long, 4.8–6.2 mm wide; surface mottled, papillate. (Figures 3, 4)

Diagnostic features. Distinct from other species of *Lambertia* Sm. on account of its orbicular, elliptic or ovate leaves with a cordate or rounded base, entire margins and glabrous lower surface. One of three species in the genus with outward-facing flowers.

Phenology. Flowering (and presumably fruiting) throughout the year, with peak flowering in summer and early autumn.

Distribution and habitat. Endemic to the Jarrah Forest and Warren bioregions in south-western Australia where it is currently known from three, disjunct population centres near Narrikup, east of Augusta and south-west of Bowelling. Grows in sand or sandy clay over laterite on plains, gentle hillslopes and low ridges, sometimes in seasonally wet areas, along riverbanks or adjacent to floodplains, in open woodland, tall shrubland over dense heath, and Proteaceous thickets.

Conservation status. Listed as Endangered under the federal *Environment Protection and Biodiversity Conservation Act 1999* (Department of Climate Change, Energy, the Environment and Water 2022). Threats to the species are disease caused by *Phytophthora cinnamomi* and aerial cankers (*Cryptodiaporthe* sp., *Diplodina* sp.), climate change, inappropriate fire regimes, grazing by feral and native herbivores, road, track and firebreak maintenance, weed invasion and salinity (Luu & English 2004; Phillimore & Brown 2002).

Notes. *Lambertia orbifolia* shares outward-facing flowers with *L. inermis* R.Br. and *L. ericifolia* R.Br., both of which have narrower leaves with revolute margins and a dense indumentum on the undersurface. It is a non-serotinous, obligate seeder (Sage & Lamont 1994). Three subspecies are recognised.

1 Bracts strongly recurved, densely hairy distally on both surfaces; inner bracts 12–20 mm long. Outer surface of perianth tube with hairs (0.5–)1–3 mm long. Young branchlet indumentum of long, ± spreading hairs over dense crispate hairs [Narrikup] ..... subsp. **orbifolia**

1. Bracts usually erect, the outer ones sometimes weakly recurved, outer surface glabrous or scarcely papillose, inner surface densely to sparsely hairy distally (rarely glabrous); inner bracts 18–28 mm long. Outer surface of perianth tube with hairs (0.5–)1–3 mm long. Young branchlet indumentum usually of long, ± spreading hairs over dense crispate hairs, rarely with longer hairs absent [Scott River Plain] ....subsp. **vespera**

1: Bracts erect or weakly to strongly recurved, densely hairy distally on both surfaces; inner bracts 15–23 mm long. Outer surface of perianth tube with inconspicuous hairs mostly to 0.2 mm long, sometimes with sparse hairs to 0.5(–1.5) mm long. Young branchlet indumentum of short, ± even, crispate hairs [SW Bowelling] ....subsp. **pecuniosa**

Lambertia orbifolia C.A.Gardner **subsp. orbifolia**

Lambertia orbifolia C.A.Gardner subsp. *orbifolia* ms, Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 10 November 2022].

Illustrations. A.S. George, *An introduction to the Proteaceae of Western Australia* 88, Plate 131 (1984); R.M. Sainsbury, *A field guide to smokebushes and honeysuckles (*Conospermum *and* Lambertia*)* 87 (1991); R.J. Hnatiuk, *Flora of Australia* 16: 434, Figure 185B–E (1995).

Shrub 2–3.5 m high. *Young branchlets* with a mixed indumentum of ± spreading hairs over a dense layer of shorter, crispate hairs. *Leaf lamina* 9–35 mm long, 9–30 mm wide, base cordate or rounded. *Bracts* strongly recurved, tomentose to pubescent on both surfaces and margins, hairs very dense distally, becoming glabrous towards base; inner bracts 12–20 mm long. *Perianth* red or orange-red with brownish or yellowish brown limbs; outer surface of tube with hairs (0.5–)1–3 mm long. (Figure 3A)

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 30 Nov. 1999, *S. Barrett* 816 (PERTH); 23 Apr. 2013, *S. Barrett* 2151 (MEL *n.v.*, PERTH); 26 Feb. 2014, *J.A. Cochrane, S. Barrett & E. Harper* JAC 8313 (PERTH); 6 May 1964, *A.S. George* 6217 (PERTH); 25 Jan. 1995, *B.G. Hammersley* 1329 (PERTH); 9 Aug. 1980, *N.G. Marchant* 80/70 (CANB *n.v.*, PERTH); 22 Jan. 1964, *K.R. Newbey* 1231 (PERTH); 29 Jan. 2003, *A. Spooner* SEAS 12 C (PERTH).

Flowering period. Flowering throughout the year. Sage and Lamont (1994) noted peak flowering occurred in January and February, and from May to July.

Distribution and habitat. Restricted to the Narrikup area in the Southern Jarrah Forest; the type population from the King River is apparently no longer extant. Grows in sand over laterite on plains, gentle hillslopes and low ridges in *Eucalyptus marginata*, *Corymbia calophylla* and *Banksia grandis* woodland with associated species such as *Nuytsia floribunda*, *Agonis theiformis*, *Taxandria parviceps*, *Hakea ferruginea* and *Leucopogon verticillatus*.

Conservation status. Listed as Threatened (Critically Endangered) in Western Australia (State of Western Australia 2022), as *L. orbifolia* subsp. *orbifolia* ms.

Vernacular name. Round-leaf Honeysuckle.

Lambertia orbifolia subsp. **vespera** A.D.Webb, L.T.Monks & Wege, *subsp. nov.*

Type: Scott River Plain, north-east of Augusta, Western Australia [precise locality withheld for conservation reasons], 20 December 2021, *J.A. Wege & B.P. Miller* JAW 2193 (*holo*: PERTH 09444807 [sheet 1 of 2], PERTH 09444815 [sheet 2 of 2]; *iso*: NSW).

Lambertia orbifolia subsp. Scott River Plains (L.W. Sage 684), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 10 November 2022].

Shrub or small tree 2–5 m high. *Young branchlets* usually with a mixed indumentum of ± spreading hairs over a dense layer of shorter, crispate hairs, rarely with the longer hairs apparently absent. *Leaf lamina* 10–50 mm long, 10–40 mm wide, base cordate or rounded. *Bracts* usually straight or sometimes with the outmost ones weakly recurved, sparsely hairy on margins, outer surface glabrous or scarcely papillose, inner surface densely to very sparsely pubescent distally (rarely completely glabrous); inner bracts 18–28 mm long. *Perianth* red or orange-red with brownish limbs; outer surface of tube with hairs (0.5–)1–3 mm long. (Figure 3B–D)

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 18 Jan. 1996, *J.A. Cochrane* JAC 1909 (PERTH); 18 Feb. 1997, *J.A. Cochrane* JAC 2339 (PERTH); 16 Jan. 2007, *J.A. Cochrane*, *S. Gale, M. Spencer & J. Liddelow* JAC 6325 (PERTH); 11 Oct. 1991, *C.J. Robinson* 782 (PERTH); 17 Jan. 1945, *R.D. Royce* 67 (PERTH); 28 Sep. 1994, *L.W. Sage* 684 (PERTH); 20 Nov. 1996, *A. Webb* AW 023 (PERTH).

Flowering period. Flowers have been recorded from September to May, with peak flowering in January and February (Sage & Lamont 1994).

Distribution and habitat. Known only from the Scott River plain, east of Augusta and mostly in the Warren bioregion, where it is restricted to the 'Scott River Ironstone Association' threatened ecological community (Luu & English 2004); a collection made in 1969 from Busselton (PERTH 01040766) is either a locality error or the population is no longer extant. Grows in sand or sandy clay in association with ironstone, around seasonally wet areas near the coast or further inland on riverbanks or more upland plains. Associated vegetation is open woodland of *Eucalyptus marginata*, *Corymbia calophylla* or *Agonis flexuosa* over closed shrubland, or shrubland over dense heath. It can form thickets in association with *Banksia littoralis*, *B. ilicifolia*, *B. grandis* and *Hakea prostrata*, and is often recorded

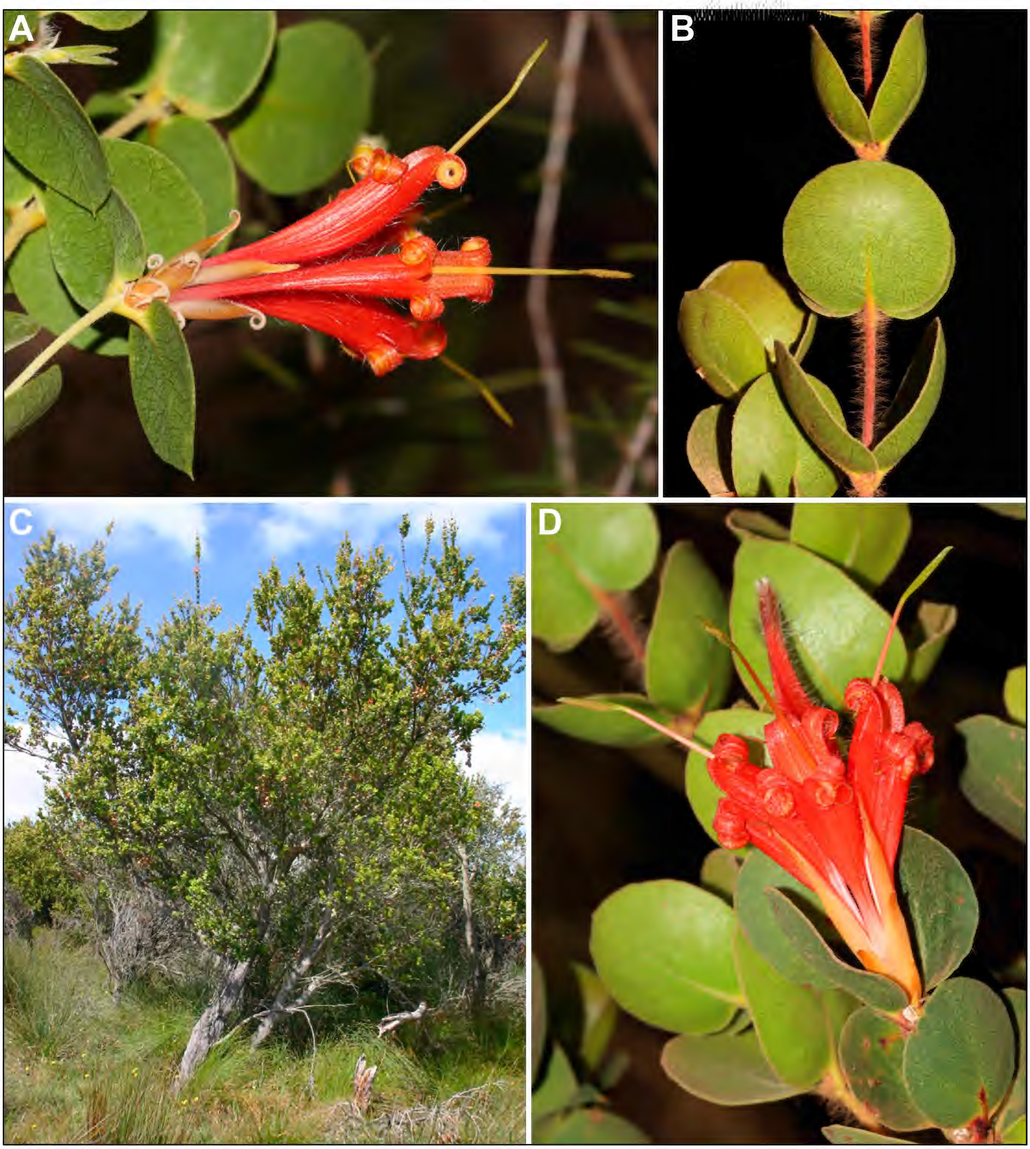

Figure 3. *Lambertia orbifolia*. A – subsp. *orbifolia*, showing the outwards-facing flowers characteristic of the species, long hairs on the perianth tube (also characteristic of subsp. *vespera*), and strongly recurved bracts; B – young stem portion of subsp. *vespera* showing the long hairs that occur with much shorter, crispate hairs (also characteristic of subsp. *orbifolia*); C – habit of subsp. *vespera*; D – inflorescence of subsp. *vespera* showing the long, straight, inner bracts that have a glabrous or scarcely papillose outer surface. Photographs by J.A. Wege from a mature plant at the Western Australian Botanic Garden (Kings Park) that was grown from seed sourced from the Narrikup area (A), J.A. Wege from PERTH 09444815 (B, D), and L. Monks from PERTH 07464029 (C).

growing with *Calothamnus lateralis* var. *crassus* and *Kunzea recurva*, or with *Taxandria juniperina* in riparian habitats.

Conservation status. Listed as Threatened (Endangered) in Western Australia (State of Western Australia 2022), as *L. orbifolia* subsp. Scott River Plains (L.W. Sage 684).

Etymology. From the Latin *vesperus* (of the evening, western), a reference to its distribution.

Vernacular name. Scott River Honeysuckle.

Lambertia orbifolia subsp. **pecuniosa** A.D.Webb, L.T.Monks & Wege, *subsp. nov.*

Type: south-west of Bowelling, Western Australia [precise locality withheld for conservation reasons], 8 February 2022, *J.A. Wege, L. Monks, A. Webb & T. Cartagena* JAW 2195 (*holo*: PERTH 09444823; *iso*: MEL, NSW).

Lambertia orbifolia subsp. Bowelling (A. Webb AW 09107), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 10 November 2022].

Shrub or small tree 2.5–6 m high. Young branchlets with a short, dense indumentum of crisped or more rarely antrorse hairs mostly to *c.* 0.2 mm long (to 0.3 mm long near leaf insertion). *Leaf lamina* 8–30 mm long, 7–28 mm wide, base rounded (rarely cordate). *Bracts* erect or more often weakly to strongly recurved, tomentose to pubescent on both surfaces and margins with the hairs very dense distally, becoming glabrous towards base; inner bracts 15–23 mm long. *Perianth* red with yellow or brownish limbs; outer surface of tube inconspicuously hairy, the hairs mostly to 0.2 mm long, with very sparse hairs to 0.5(–1.5) mm long. (Figure 4)

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 21 Feb. 2020, *A. Webb* AW 09107 (AD, PERTH); 5 Mar. 2021, *A. Webb* AW 09127 (PERTH); 13 Jan. 2022, *A. Webb* AW 09129 (CANB, MEL, NSW, PERTH); 8 Feb. 2022, *J.A. Wege, L. Monks, A. Webb & T. Cartagena* JAW 2196 (PERTH).

Flowering period. Flowering has been recorded from January to March.

Distribution and habitat. Currently known from two population centres associated with a tributary of the east branch of the Collie River, south-west of Bowelling in the Southern Jarrah Forest. At the type locality it grows in sand overlying clay at depth in the ecotone between floodplain and dryland vegetation, in open *Eucalyptus wandoo* and *E. rudis* woodland with *Banksia attenuata*, *B. littoralis*, *Melaleuca preissiana* and *Nuytsia floribunda*. At the second locality it occurs on lower hillslopes in loamy sand or sand over laterite (probably with clay at depth), in *Eucalyptus marginata* and *Banksia attenuata* woodland, and is dominant in the middle-storey alongside *B. sessilis*.

Conservation status. Listed as Priority Two under Conservation Codes for Western Australian flora (Western Australian Herbarium 1998–), as *L. orbifolia* subsp. Bowelling (A. Webb AW 09107). Recent targeted surveys suggest that this taxon is highly localised and is likely to warrant listing as Threatened. There are two populations, one of which occurs in a Conservation Park, and threats include mining, feral pig activity, and *Phytophthora* dieback disease.

Etymology. The epithet is from the Latin *pecuniosus* (moneyed, rich, wealthy) and is a reference to the penny-like leaves. Local property owners have long been aware of this taxon, referring to it as ‘Penny Bush’.

Vernacular name. Penny-leaved Honeysuckle.

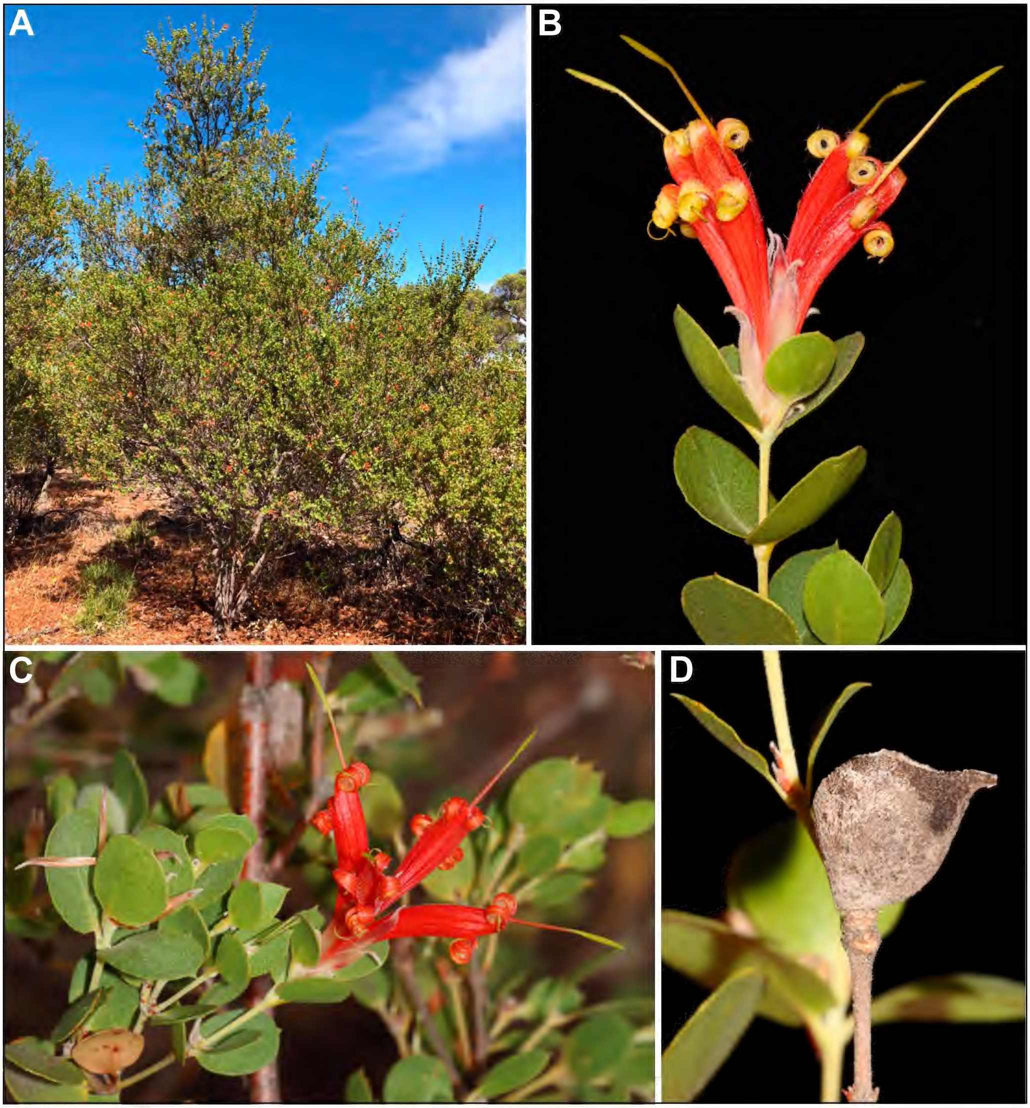

Figure 4. *Lambertia orbifolia* subsp. *pecuniosa*. A – habit; B – flowering branchlet showing the hairy bracts with a weakly to strongly recurved tip and yellow perianth limbs. Note the young stem has consistently short (rather than both long and short) hairs, and the hairs on the perianth tube are mostly very short; C – flowering branchlet showing reddish perianth limbs; D – fruit. Photographs by J.A. Wege from PERTH 09444823 (A, B, D) and PERTH 09444831 (C).

Acknowledgements

We thank staff at the Western Australian Herbarium for curatorial support, Tayla Cartagena for field assistance and survey effort, Amanda Shade for onsite support at Kings Park, and Kelly Shepherd and an anonymous reviewer for their time and comments.

References

Atkins, K.J. (1999). *Declared rare and priority flora list for Western Australia, 20 Dec. 1999*. (Department of Conservation & Land Management: Como, Western Australia.)

Byrne, M., MacDonald, B. & Coates, D. (1999). Divergence in the chloroplast genome and nuclear rDNA of the rare Western Australian plant *Lambertia orbifolia* Gardner (Proteaceae). *Molecular Ecology* 8: 1789–1796.

Coates, D.J. & Hamley, V.L. (1999). Genetic divergence and the mating system in the endangered and geographically restricted species *Lambertia orbifolia* Gardner (Proteaceae). *Heredity* 83: 418–427.

Department of Climate Change, Energy, the Environment and Water (2022). *Lambertia orbifolia* in Species Profile and Threats Database, Department of Climate Change, Energy, the Environment and Water, Canberra. Available at https://www.environment.gov.au/sprat [accessed 4 January 2022].

Gardner, C.A. (1964). Contributiones Florae Australiae occidentalis XIII. *Journal of the Royal Society of Western Australia* 47: 54–64.

George, A.S. (1984). *An introduction to the Proteaceae of Western Australia.* (Kangaroo Press: Kenthurst, New South Wales.)

Hnatiuk, R.J. (1995). *Lambertia*. *Flora of Australia* 16: 425–436.

Luu, R. & English, V. (2004). *Interim Recovery Plan No. 178. Scott River* Lambertia *(*Lambertia orbifolia *subsp. Scott River Plains)*. (Department of Conservation and Land Management: Wanneroo, Western Australia.)

Monks, L., Standish, R., McArthur, S., Dillon, R., Byrne, M. & Coates, D. (2021). Genetic and mating system assessment of translocation success of the long-lived perennial shrub *Lambertia orbifolia* (Proteaceae). *Restoration Ecology* 29(5): e13369.

Phillimore, R. & Brown, A. (2002). *Interim Recovery Plan No. 115. Round-leafed Honeysuckle (*Lambertia orbifolia *subsp.* orbifolia *ms)*. (Department of Conservation and Land Management: Wanneroo, Western Australia.)

Sage, L. & Lamont, B.B. (1994). *Conservation biology of the rare and endangered species* Lambertia orbifolia. Unpublished report for Dr. D. Coates, Science and Information Branch, Department of Conservation and Land Management. (Curtin University, School of Environmental Biology: Western Australia.)

State of Western Australia (2022). Biodiversity Conservation (Listing of Native Species) (Flora) Order 2022. Western Australian Government Gazette 2022(144): 4763–4768. https://www.legislation.wa.gov.au/legislation/statutes.nsf/gazettes2022.html

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au/ [accessed 10 November 2022].

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01056

Nuytsia 34: 139–155
Published online 20 July 2023

The taxonomy of the *Styphelia corynocarpa* subgroup (Ericaceae: Epacridoideae: Styphelieae)

Michael Hislop

Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983

Abstract

Hislop, M. The taxonomy of the *Styphelia corynocarpa* subgroup (Ericaceae: Epacridoideae: Styphelieae). *Nuytsia* 34: 139–155 (2023). A small subgroup within the heterogeneous *Styphelia* Sm. Group X is recognised based on morphological and molecular data. A morphological synopsis of, and key to, the subgroup are provided, and all four member species are described and illustrated. Three of the four species are described as new, *S. anomala* Hislop, *S. cylindrica* Hislop and *S. planiconvexa* Hislop, while *S. corynocarpa* (Sond.) F.Muell. is given an updated description. *Styphelia anomala* has Western Australian conservation listing as Priority two.

Introduction

Group X is the most morphologically diverse of the 12 phylogenetic groups resolved in *Styphelia* Sm. by Puente-Lelièvre *et al.* (2016). In a recent paper Hislop and Nguyen (2022) noted that the Western Australian members of the group comprised several morphological elements that corresponded with well-supported terminal subclades in Group X, while acknowledging that some lower branch values within the group had little or no support. In that paper they treated one such subclade, to which they gave the informal name the *Styphelia tamminensis* subgroup. Another well-defined, but much smaller subgroup (the *Styphelia corynocarpa* subgroup) is reviewed here: it consists of *S. corynocarpa* (Sond.) F.Muell. and three previously undescribed species, one of which has long been confused with *S. crassifolia* (Sond.) F.Muell.

Methods

This study was based on an examination of dried specimens housed at the Western Australian Herbarium (PERTH), together with field observations of all species treated. Details of the methods used to measure plant parts and make other morphological observations are the same as those described in a recent paper (Hislop & Nguyen 2022). Sepal colour is based on observations of dried specimens.

Bioregions referred to in the text follow *Interim Biogeographic Regionalisation for Australia* (IBRA) v. 7 (Department of Climate Change, Energy, the Environment and Water 2021).

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

Taxonomy of the *Styphelia corynocarpa* subgroup

Two of the species treated here, *S. corynocarpa* and *S. cylindrica* Hislop, were included in the phylogeny published in Puente-Lelièvre *et al.* (2016), the latter as *Leucopogon crassifolius* Sond. They were shown to have a very strong sister relationship but were placed within a larger subclade for which there was very weak basal support. The placement of the other two included here in the subgroup, *S. anomala* Hislop and *S. planiconvexa* Hislop, is based on extrapolation of critical morphological features.

Morphological synopsis of subgroup

Leaves helically arranged, long-petiolate; apex non-mucronate; lamina plano-convex or concave adaxially, narrowly obovate or narrowly elliptic, gently incurved to gently recurved; abaxial surface glabrous, openly grooved. *Inflorescences* arising from the axils of regular, mature leaves, or from bract-like, 'early seasonal leaves' (*sensu* Powell *et al.* 1997: 16) that are strongly dimorphic from regular leaves (in *S. anomala*), 1–6-flowered; flowers sessile or pedicellate (in *S. cylindrica*); axis erect, either terminating in a bud-rudiment or at the flower and the bud-rudiment absent (in *S. anomala*). *Sepals* not striate, glabrous abaxially, longer than to occasionally slightly shorter than the corolla tube. *Corolla* white or cream-coloured. *Corolla tube* usually shorter than the lobes, internal surface glabrous or with a narrow band of hairs at the apex, external surface glabrous. *Corolla lobes* erect in basal 1/2–2/3 and then spreading and recurved; outer surface glabrous; inner surface densely hairy with ± terete and ornamented hairs. *Anthers* either partially exserted from the tube by at least 3/4 of their length or fully but very shortly exserted. *Filaments* terete, attached to the anther at least 3/4 above anther base, usually just below the apex, adnate to the corolla tube just below the sinuses. *Nectaries* either annular and lobed with deep longitudinal grooves below the sinuses, or partite. *Ovary* glabrous, 5-locular, pale to mid or occasionally dark green or straw-coloured to pale brown. *Style* ± scabrous in the upper half, exserted from the corolla tube but not exserted beyond the erect bases of the corolla lobes, abruptly differentiated from the obtuse or subacute ovary apex, discontinuous with ovarian tissue and often arising from a depression at the ovary apex that tightly envelops, but is free from, the style base (i.e. the base is countersunk below the level of the ovary apex). *Drupe* ± dry (mesocarp not, or poorly developed), with a well-defined gynophore, cylindrical, narrowly ellipsoid, narrowly ovoid or narrowly obovoid in shape, always much longer than the sepals.

Elsewhere within Group X, members of the *S. corynocarpa* subgroup are probably most likely to be confused with some of the narrower-leaved species from the *S. tamminensis* subgroup. Morphological features that can be used to distinguish between the two subgroups are as follows: internal corolla tube glabrous or with a sparse, narrow band of hairs at the apex (*cf.* always variously hairy in the upper half in the *S. tamminensis* subgroup); corolla lobes erect in basal 1/2–2/3 and then spreading and recurved (*cf.* usually spreading from close to the base); anthers either fully exserted from corolla tube or partially exserted by at least 3/4 of their length on filaments at least 0.5 mm long (*cf.* anthers wholly included or occasionally with just the tips exserted, the filaments very short to 0.2 mm long); style exserted from the corolla tube, ovary 5-locular (*cf.* style included, ovary 3-locular).

The morphology of two of the three taxa that grouped very weakly with *S. corynocarpa* + *S. cylindrica* in the phylogenetic tree of Puente-Lelièvre *et al.* (2016) give some limited support to a relationship with the *S. corynocarpa* subgroup. *Leucopogon* sp. Bremer Bay (K.R. Newbey 4667) and *L.* sp. Mount Heywood (M.A. Burgman 1211) have the long-petiolate leaves that are a feature of the subgroup, but their laminas are short and broad (often wider than long) and recurved along their longitudinal axes, quite unlike those of the subgroup members. Both phrase-named taxa have the relatively uncommon character of recurved sepals and are therefore similar in that respect to *S. cylindrica*. The relative lengths of sepal to corolla tube, corolla tube to corolla lobes and style to corolla tube between the two phrase-named taxa and the *S. corynocarpa* subgroup are all quite comparable. So too is the position of the anthers relative to the corolla tube and stigma. *Leucopogon* sp. Bremer Bay shares with *S. anomala* an inflorescence axis that terminates at the flower rather than a bud-rudiment, although other aspects of the inflorescence structure are dissimilar. In terms of the taxonomically important fruit character, whereas members of the *S. corynocarpa* subgroup have relatively long fruit, always much longer than the sepals, the fruit of both *L.* sp. Bremer Bay and *L.* sp. Mount Heywood varies from a little shorter than, to a little longer than, the sepals.

The third taxon that grouped weakly with *S. corynocarpa* + *S. cylindricarpa* in the larger subclade is the informal phrase-name *Leucopogon* sp. 'Koolyanobbing'. This entity is known from a single collection from a remote part of the Coolgardie bioregion. Its morphology is closest to that of *L.* sp. Jaurdi (M. Hislop 4172) although differing in several potentially significant respects. It likely represents a distinct species but with so little material available it is difficult to properly evaluate its status. The placement of *L.* sp. 'Koolyanobbing' in this subclade seems particularly problematic as in most respects its morphology closely resembles that seen in the members of the strongly supported subclade that includes *S. marginata* (W.Fitzg.) Hislop, Crayn & Puente-Lel. This apparent anomaly exemplifies the need for further genetic sampling of taxa currently referred to Group X in order to better understand relationships within that diverse grouping.

Key to species of the *S. corynocarpa* subgroup

1. Inflorescences strictly single-flowered

  2. Inflorescences arising from the axils of bract-like early seasonal leaves that are strongly dimorphic from regular leaves; inflorescence axis terminates at the flower, no bud-rudiment present; inflorescence axis bare below the bracteoles, bracts absent; drupe cylindrical to very narrowly obovoid, sometimes ± curved, 3.8–4.2 mm long (restricted: NE of Lake King) .... **S. anomala**

  2: Inflorescence arising from the axils of regular, mature leaves; inflorescence axis terminating in a bud-rudiment; inflorescence axis with a fertile bract subtending the bracteoles and with 3 or 4 sterile bracts on the axis below; drupe narrowly ellipsoid or oblongoid, 2.7–3.3 mm long (widespread: SE of Quairading–S of Bodallin–NW of Cascade–N of Borden) .... **S. planiconvexa**

1: Inflorescences multi-flowered, or a mixture of multi- and single-flowered, always some multi-flowered inflorescences present

  3. Sepals 1.7–2.4 mm long, distinctly recurved distally; flowers with a short, thick pedicel, to 0.5 mm long, present below the bracteoles; drupe cylindrical or sometimes very narrowly ovoid, often ± curved, 0.8–1.1 mm wide (W Fitzgerald River N.P.–Israelite Bay and as far inland as the Scaddan area) .... **S. cylindrica**

  3: Sepals 2.3–3.0 mm long, appressed to the corolla; flowers sessile below the bracteoles; drupe narrowly obovoid or claviform, 2.3–3.0 mm wide (W Stirling Range N.P.–W Fitzgerald River N.P.–Manypeaks area) .... **S. corynocarpa**

Species of the *S. corynocarpa* subgroup

Styphelia anomala Hislop, *sp. nov.*

Typus: north-east of Lake King, Western Australia [precise locality withheld for conservation reasons], 8 October 2006, *M. Hislop* 3659 (*holo*: PERTH 07802137; *iso*: CANB, CNS, MEL).

Leucopogon sp. Varley (M. Hislop 3659), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 3 February 2023].

Erect *shrubs*, to *c.* 80 cm high and 40 cm wide, single-stemmed at ground level with a fire-sensitive rootstock. Young *branchlets* with a sparse indumentum of very short hairs, < 0.05 mm long. *Leaves* helically arranged, steeply antrorse; apex obtuse to subacute; base attenuate or cuneate; petiole well-defined, 0.5–1.5 mm long, adaxial surface sparsely hairy or ± glabrous, abaxial surface and margins glabrous; lamina usually narrowly obovate to narrowly elliptic, occasionally elliptic, 2.0–4.8 mm long, 1.0–1.5 mm wide, slightly discolorous, thick, usually planoconvex or sometimes the adaxial surface concave, longitudinal axis straight to gently incurved; adaxial surface shiny, glabrous, the venation not evident; abaxial surface paler, shiny, glabrous, with 3 prominent primary veins, shallowly and openly grooved between the veins; margins glabrous. *Inflorescence* axillary, erect, very reduced, arising from axils of bract-like, 'early seasonal leaves' that are strongly dimorphic from regular leaves; axis 0.2–0.4 mm long, 1-flowered, terminating at the flower, bud-rudiment absent; inflorescence *bracts* absent. *Bracteoles* broadly ovate, 1.0–1.4 mm long, 0.8–1.0 mm wide, keeled, obtuse to acute; abaxial surface glabrous; margins minutely ciliolate. *Sepals* ovate or narrowly ovate, 2.2–2.7 mm long, 1.0–1.2 mm wide, obtuse to acute, the apex appressed to the corolla; abaxial surface glabrous, straw-coloured, the mid-vein usually well-defined and often 1 or 2 veins on either side also evident; adaxial surface with a discrete patch of hairs at the base and with some hairs in the upper half; margins minutely ciliolate with hairs < 0.05 mm long or ± glabrous. *Corolla tube* cream-coloured, obovoid, slightly shorter than to slightly longer than the sepals, 1.8–2.2 mm long, 1.4–1.7 mm wide, glabrous externally, internal surface with a narrow transverse band of hairs at the apex, glabrous below. *Corolla lobes* cream-coloured, *c.* equal to or longer than the tube, 2.0–3.0 mm long, 0.6–0.8 mm wide at base, erect in basal 1/2–2/3 and then spreading and recurved, glabrous externally, internal surface with a dense indumentum of ± terete, distinctly ornamented hairs. *Anthers* partially exserted from the tube by 3/4–7/8 of their length, 0.6–0.8 mm long, apex ± emarginate. *Filaments* terete, 0.5–0.6 mm long, attached to anther just below the apex, adnate to tube just below the sinuses. *Nectary* either annular and lobed with deep longitudinal grooves below the sinuses, or clearly partite with scales 0.3–0.4 mm long, 0.3–0.3 mm wide, glabrous with the upper margins minutely papillose. *Ovary* obovoid to ellipsoid, 0.6–0.7 mm long, 0.4–0.5 mm wide, glabrous, 5-locular, pale to mid green. *Style* green below, straw-coloured above, abruptly differentiated from ovary apex, 1.8–2.3 mm long, slightly scabrous in the upper half, shortly exserted from the corolla tube, but not beyond the erect bases of the corolla lobes, discontinuous with ovarian tissue and arising from a depression at the ovary apex that tightly envelops, but is free from, the style base (i.e. the base is countersunk below the level of the ovary apex); stigma barely expanded. *Fruit* cylindrical to very narrowly obovoid, sometimes ± curved, 3.8–4.2 mm long, 1.0–1.2 mm wide (measurements based on very limited material), much longer than the sepals, circular in transverse section, with a well-defined gynophore; surface glabrous, shiny, green to mid-brown, smooth (mesocarp poorly developed), with pale longitudinal lines; apex obtuse; style shed before maturity. (Figure 1)

Diagnostic characters. Within the *S. corynocarpa* subgroup, distinguished by the following character combination: leaf lamina thick, usually plano-convex, or less often concave adaxially, with 3 promi-

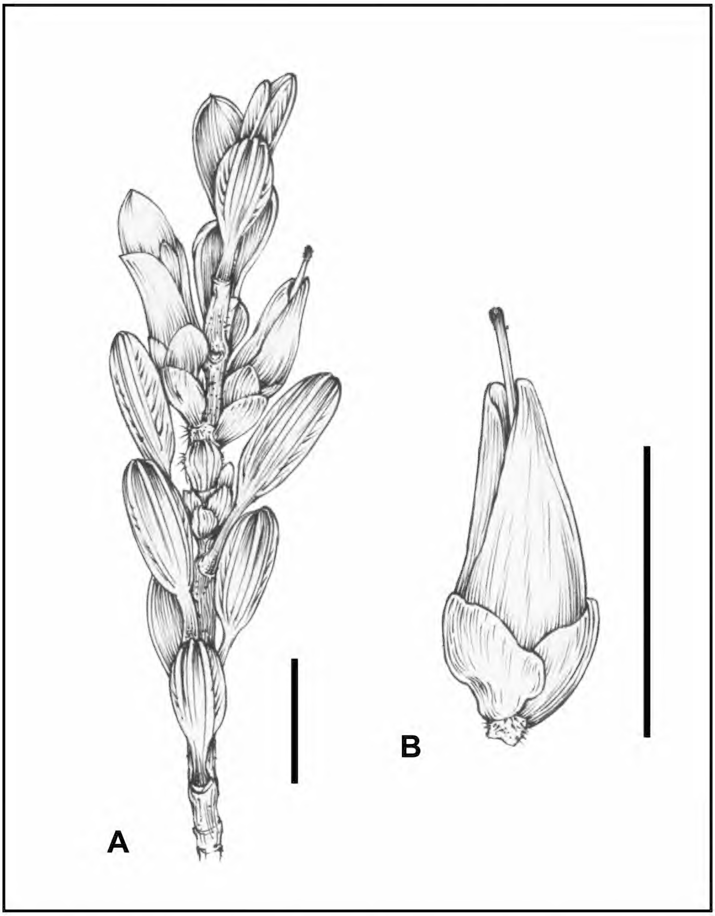

Figure 1. *Styphelia anomala*. A – flowering branchlet, showing inflorescences arising from bract-like, early seasonal leaves; B – inflorescence, showing bracteoles and sepals and the absence of bracts and bud rudiment. Scale bars = 2 mm. Voucher *M. Hislop* 3659. Drawings by Hung Ky Nguyen.

nent abaxial veins, shallowly and openly grooved between the veins; inflorescence strictly arising from the axils of bract-like, early seasonal leaves, axis 0.2–0.4 mm long, inflorescence bracts absent below the bracteoles, terminating at the flower, bud-rudiment absent; sepals appressed to the corolla; fruit cylindrical to very narrowly obovoid, sometimes ± curved, 3.8–4.2 mm long, 1.0–1.2 mm wide.

Other specimen examined. WESTERN AUSTRALIA: [locality withheld for conservation reasons] 14 Nov. 1979, *K.R. Newbey* 6540 (PERTH).

Distribution and habitat. Currently only known from a small area north-east of Lake King in the central portion of the Mallee bioregion, where it grows in sandy loam over laterite. Associated vegetation is low heathland.

Phenology. The two collections of the species at the Western Australian Herbarium are more or less in full flower, one in October, the other in November. Both also have a few fruit present.

Etymology. From the Latin *anomalus* (anomalous, abnormal), a reference to the highly unusual configuration of the inflorescence.

Conservation status. Currently listed as Priority Two (Western Australian Herbarium 1998–) under Conservation Codes for Western Australian Flora under the name *Leucopogon* sp. Varley (M. Hislop 3659). The species is only known from two records north-east of Lake King, one of which is just within the boundary of Frank Hann National Park. Because this is a remote and difficult-to-access part of the state, and the preferred habitat of the species is a common one in the area, there is a strong likelihood that further populations will come to light over time. Still, it does seem very unlikely that it is widely distributed.

Affinities. *Styphelia anomala* was not included in the phylogeny of Puente-Lelièvre *et al.* (2016), but aside from the anomalous inflorescence features, other floral and foliar characteristics strongly indicate that its affinities lie with members of the *S. corynocarpa* subgroup, especially *S. cylindrica*.

Two aspects of the inflorescence structure of *S. anomala* are unusual in the *Styphelieae* generally. While some species will produce inflorescences from the axils of 'early seasonal leaves' (*sensu* Powell *et al.* 1997: 16) as well as those of regular, mature leaves, *S. anomala* is the only example known to the author where inflorescences are restricted to the former. The other anomalous feature is that the single-flowered inflorescence axis terminates at the flower, with no bud-rudiment present, and no inflorescence bracts below the two bracteoles. In this regard it is similar to species from the *S. blepharolepis* group (or Group XI *sensu* Puente-Lelièvre *et al.* 2016), although in that group multiflowered inflorescences co-occur with single-flowered, and the former do have fertile bracts and terminate in a bud-rudiment. These inflorescence features readily distinguish *S. anomala* from its congeners in the *S. corynocarpa* subgroup, which all have regular inflorescences with fertile and sterile bracts and terminate with a bud-rudiment.

The distribution of *S. anomala* lies within that of the widespread *S. planiconvexa* Hislop, described below. The two species share a consistently single-flowered inflorescence and could therefore be confused. Aside from the distinction in inflorescence structure as explained above, the fruit size and shape of the two species is significantly different: cylindrical to very narrowly obovoid, sometimes ± curved and 3.8–4.2 mm long in *S. anomala*, *cf.* narrowly ellipsoid or oblongoid, 2.7–3.3 mm long in *S. planiconvexa*. And whereas the latter species has a red or pink style and frequently pink-flushed sepals, in *S. anomala* the style is straw-coloured and green and the sepals straw-coloured.

The mostly cylindrical fruit of *S. anomala* is very similar to that of *S. cylindrica* and it seems likely that the two are each other's closest relative. In addition to the different inflorescence arrangement, *S. anomala* can be readily distinguished by sepal posture: appressed to the corolla in *S. anomala cf.* prominently recurved in the upper half in *S. cylindrica*. The distribution of *S. anomala* lies disjunctly to the north of that of *S. cylindrica*, with the northernmost population of the latter occurring about 85 km distant from the nearest population of *S. anomala*, based on current data.

Styphelia corynocarpa (Sond.) F.Muell., *Syst. Census Austral. Pl.* 107 (1882); *Leucopogon corynocarpus* Sond. in J.G.C. Lehmann, *Pl. Preiss.* 1(3): 322 (1845). *Typus*: In Novae Hollandiae ora merid.-occid. prope promontorium Cape Riche [south coast of Western Australia], Nov. 1840, *L. Preiss* 379 (ex parte) (syn: LD 1803361 image!, MEL 1510198B!).

Erect, open *shrubs*, to *c.* 150 cm high and 80 cm wide, single-stemmed at ground level with a fire-sensitive rootstock. Young *branchlets* with a sparse to moderately dense indumentum of very short hairs, < 0.05 mm long. *Leaves* helically arranged, steeply antrorse; apex obtuse to acute, if acute terminating in blunt callus tip to 0.2 mm long; base usually attenuate, sometimes ± cuneate; petiole well-defined, 0.8–2.0 mm long, adaxial surface shortly hairy, abaxial surface glabrous, margins glabrous or sparsely hairy; lamina narrowly obovate to narrowly elliptic, 4.0–13.0 mm long, 1.0–2.2 mm wide, discolorous, concave adaxially, longitudinal axis gently incurved to gently recurved; adaxial surface shiny, glabrous or with a few hairs towards the base, the venation not evident or appearing as indistinct sunken lines in the lower half; abaxial surface paler, shiny, glabrous, with 3–5 prominent, primary veins, shallowly to quite deeply and openly grooved between the veins; margins ± glabrous or with minute, coarse, antrorse hairs, < 0.05 mm long. *Inflorescence* axillary, erect, arising from axils of regular, mature leaves; axis 2.0–8.0 mm long, (1)2–5(6)-flowered, ± terete towards the base, angular above, with a moderately dense indumentum of short hairs, terminating in a bud-rudiment; flowers erect, sessile. *Fertile bracts* variable, from depressed-ovate to ovate, 0.7–1.2 mm long, 0.7–1.0 mm wide, subtended by 3–5 sterile bracts. *Bracteoles* ovate, broadly ovate to ± orbicular, 1.2–1.5 mm long, 1.0–1.2 mm wide, keeled, sometimes rather obscurely, obtuse to subacute; abaxial surface glabrous; margins ciliolate. *Sepals* ovate to narrowly ovate, 2.3–3.0 mm long, 1.0–1.3 mm wide, obtuse to acute, the apex appressed to the corolla; abaxial surface glabrous, straw-coloured, the mid-vein and sometimes 2 or 3 either side usually evident; adaxial surface with discrete patches of hair towards the base and apex; margins ciliolate with hairs < 0.05 mm long or ± glabrous. *Corolla tube* white, but usually drying dark reddish-brown, broadly obovoid or obovoid, shorter than the sepals, 1.4–1.8 mm long, 1.3–1.7 mm wide, glabrous externally and internally. *Corolla lobes* white, longer than the tube, 2.2–2.8 mm long, 0.7–0.9 mm wide at base, erect in the lower 1/2–2/3 and then spreading and ± recurved, glabrous externally, internal surfaces with a dense indumentum of ± terete, distinctly ornamented hairs. *Anthers* either partially exserted from the tube by at least 7/8 of their length or ± fully exserted, 0.6–1.0 mm long, apex ± emarginate. *Filaments* terete, 0.5–0.6 mm long, attached to anther just below the apex, adnate to tube just below the sinuses. *Nectary* very thick, either annular and lobed with deep longitudinal grooves below the sinuses, or ± partite with scales 0.3–0.4 mm long, 0.2–0.3 mm wide, glabrous with the upper margins papillose. *Ovary* obovoid to broadly obovoid, 0.5–0.7 mm long, 0.5–0.7 mm wide, glabrous, 5-locular, mid green or pale brown. *Style* straw-coloured, abruptly differentiated from the ovary apex, 1.6–2.1 mm long, scabrous at least in the upper half, shortly exserted from the corolla tube, but not beyond the erect bases of the corolla lobes, discontinuous with ovarian tissue and usually arising from a depression at the ovary apex that tightly envelops, but is free from, the style base, or less often apparently arising directly from the ovary apex; stigma slightly expanded. *Fruit* narrowly obovoid or claviform, 4.0–6.2 mm long, 2.3–3.0 mm wide, much longer than the sepals, circular in transverse section, with a well-defined gynophore; surface glabrous, shiny, brown or dark green, ± dry, smooth (mesocarp poorly developed), with pale longitudinal lines; apex obtuse to subacute; style shed before maturity. (Figures 2A, 3A)

Other specimens examined. WESTERN AUSTRALIA: Hume Peak, Stirling Range National Park, 6 Oct. 1995, *S. Barrett* 589 (PERTH); Formby South Rd, 2.1 km W of junction with Chester Pass Rd, Stirling Range National Park, 24 Oct. 1997, *E.A. Brown* 97/411, *P.G. Wilson & N. Lam* (NSW, PERTH); Along Sandlewood Rd [S of Borden], 11 Oct. 2013, *G. Byrne* 4912 (PERTH); [intersection] Millers Point Rd and Bremer Bay Rd, 8 Nov. 1978, *R.J. Cranfield* 1107 (CANB, PERTH); Wellstead, *c.* 95 km NE of Albany, 8 Nov. 1978, *R.J. Cranfield* 1115 (CANB, PERTH); 4.9 km E along Chillinup Rd from junction with Kojaneerup West Rd [South Stirling], 20 Nov. 2013, *R. Davis & M. Davis* RD 12388 (PERTH); 5½ miles [*c.* 8.8 km] E of Manypeaks, 10 Dec. 1964, *A.S. George* 6490 (PERTH); Fitzgerald River National Park, 1–2 km N of Quaalup Homestead, 19 Oct. 1991, *W. Greuter* 22976 (PERTH); mid NW slopes of Barnett Peak, Stirling Range National Park, 2 June 2001, *M. Hislop* 2215 (PERTH); Hamilla Hill Reserve [E of Cranbrook], central upland, 30 Dec. 2001, *M. Hislop* 2524 (PERTH); Moorialup Reserve, off Moorialup Rd, 4 km E of Takalarup Rd, E of Porongurup, 16 Nov. 2003,

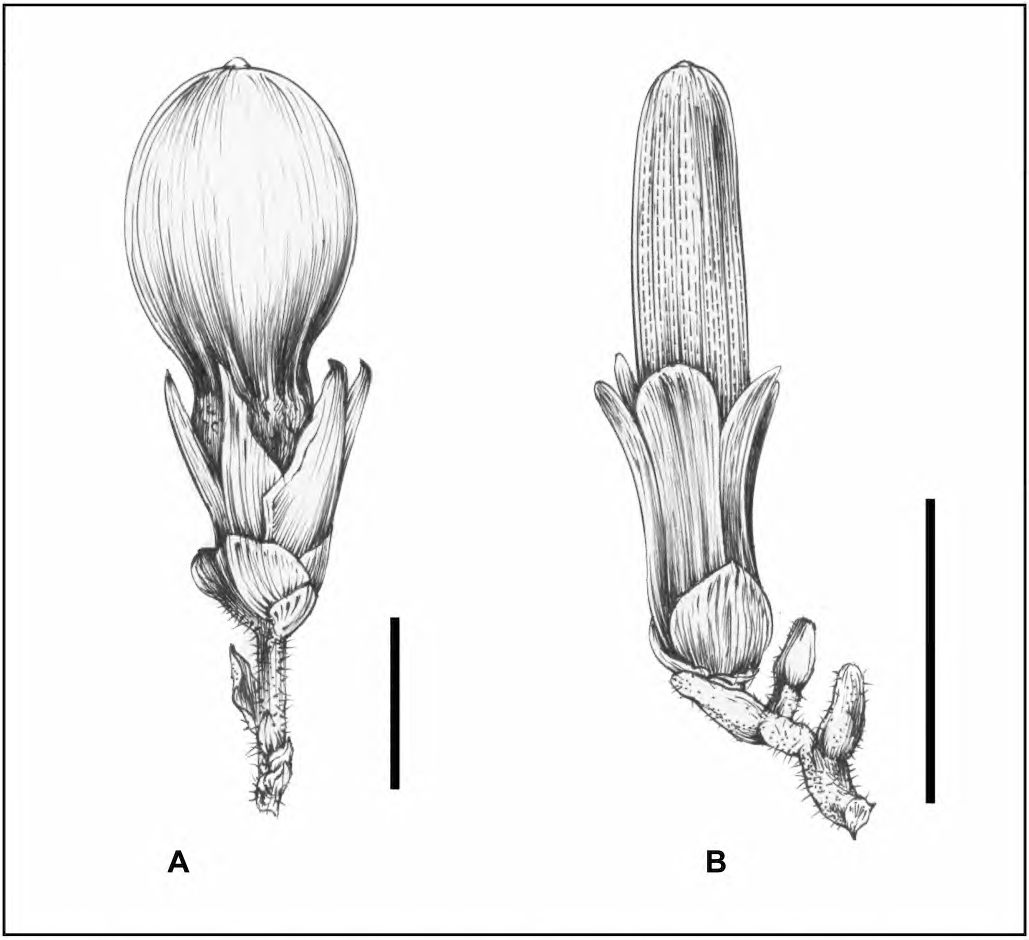

Figure 2. A – *Styphelia corynocarpa*, fruiting inflorescence; B – *Styphelia cylindrica*, fruiting inflorescence. Scale bars = 2 mm. Vouchers *R.J. Hnatiuk* 761411 (A), *M. Hislop* 2289 (B). Drawings by Hung Ky Nguyen.

M. Hislop 3085 (CNS, PERTH); *c.* 10 km S of South Bluff, Stirling Range National Park, 28 Oct. 1976, *R.J. Hnatiuk* 761411 (PERTH); Takenup, Kalgan River, 10 Nov. 1982, *G.J. Keighery* 5898 (PERTH); quadrat 3, Reserve 13240, Cheynes Bay, N of Cape Riche, 24 Oct. 1996, *J.W. Mercer* 54 (PERTH); 0.8 km W of Mt Maxwell turnoff [Fitzgerald River National Park], 2 Aug. 1986, *J.M. Powell* 2396 (HO, K, NSW, PERTH); Mettlers Lake Rd, SW of Wellstead, 3 Aug. 1986, *J.M. Powell* 2431 (HO, K, NSW, PERTH); Pillenorup track, 1–2 km W from Gold Holes, Stirling Range National Park, 30 Aug. 1986, *J.M. Powell* 2728B (NSW, PERTH); junction of Devils Creek Rd and track to Mt Maxwell, 17 Nov. 1985 *J.M. Powell* 3338 (NSW, NY, PERTH); 0.4 km N of Quaalup Homestead on Gairdner Rd [Fitzgerald River National Park], 16 July 2010, *C. Puente-Lelievre & E.A. Brown* CPL 97 (NSW, PERTH); Murray Rd, halfway between Gordon Inlet Rd and Devils Creek Rd [NNW of Bremer Bay], 23 Oct. 1982, *A. Strid* 20949 (PERTH).

Distribution and habitat. Distributed from the western end of the Stirling Range National Park to western parts of the Fitzgerald River National Park, and south to the Manypeaks area; in the Esperance

Plains and far southern tip of the Jarrah Forest bioregions. Grows in deep sand or in sand over laterite or quartzite, often high in the landscape. Associated vegetation is mostly heath or open mallee woodland.

Phenology. Peak flowering is between October and December, but collections with some flowers present have been made in all seasons of the year. The conspicuous, shiny fruit are apparently persistent on plants for many months and are frequently present on flowering collections.

Conservation status. Although not having a particularly wide distribution, the species is often locally common and is well represented on the conservation estate. No conservation listing is recommended here.

Styphelia cylindrica Hislop, *sp. nov.*

Typus: 28.3 km from Mylies Beach turnoff, 10.5 km from Telegraph track on Hamersley Drive, Fitzgerald River National Park, Western Australia, 14 July 1982, *J.M. Powell* 1824 (*holo*: PERTH 02953897!; *iso*: CANB 310798 *n.v.*, K *n.v.*, L *n.v.*, MEL 0629359 *n.v.*, NSW 406098 *n.v.*).

Styphelia sp. South Coast (J.M. Powell 3374), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 3 February 2023].

Leucopogon crassifolius auct. non Sond.: G. Bentham, *Fl. Austral.* 4: 224 (1868); W.E. Blackall & B.J. Grieve, *How to Know W. Austral. Wildfl.* IIIB: 344, 349 (1981); G. Paczkowska & A.R. Chapman, *West. Aust. Fl.: Descr. Cat.*: 237 (2000); Western Australian Herbarium, in *Florabase,* https://florabase.dpaw.wa.gov.au/ [before March 2018].

Erect, open *shrubs*, to *c.* 120 cm high and 80 cm wide, single-stemmed at ground level with a fire-sensitive rootstock. Young *branchlets* with a sparse to moderately dense indumentum of very short hairs, < 0.05 mm long. *Leaves* helically arranged, steeply antrorse; apex obtuse to acute, if acute terminating in a blunt callus tip to 0.2 mm long; base usually attenuate, occasionally ± cuneate; petiole well-defined, 0.4–1.8 mm long, adaxial surface shortly hairy, abaxial surface and margins glabrous or occasionally the margins with a few hairs; lamina narrowly obovate to narrowly elliptic, 2.5–5.5 mm long, 0.8–1.8 mm wide, discolorous, thick, either concave adaxially or plano-convex, longitudinal axis gently incurved to gently recurved; adaxial surface shiny, glabrous or with a few hairs towards the base, the venation not evident; abaxial surface paler, shiny, glabrous, with 3 prominent, primary veins, shallowly to deeply and openly grooved between the veins; margins usually glabrous or sometimes with minute, coarse, antrorse hairs, < 0.05 mm long. *Inflorescence* axillary, erect, arising from axils of regular, mature leaves; axis 1.0–4.5 mm long, 1–4-flowered, ± terete towards the base, bluntly angular above, with a sparse to moderately dense indumentum, terminating in a bud-rudiment; flowers erect, shortly pedicellate below the bracteoles, with a pedicel to 0.5 mm long. *Fertile bracts* ovate or broadly ovate, 0.5–0.8 mm long, 0.4–0.5 mm wide, subtended by 0–2 sterile bracts. *Bracteoles* ovate or broadly ovate, 0.8–1.3 mm long, 0.7–1.0 mm wide, keeled, obtuse; abaxial surface glabrous; margins ciliolate. *Sepals* narrowly ovate to oblong, 1.7–2.4 mm long, 0.6–1.0 mm wide, usually obtuse, less often subacute, distinctly recurved in the upper half; abaxial surface glabrous, straw-coloured, the mid-vein usually well-defined and often 1 or 2 veins on either side also evident; adaxial surface with a discrete patch of hairs at the base and sometimes also with some hairs in the upper half; margins minutely and irregularly ciliolate with hairs < 0.05 mm long or ± glabrous. *Corolla tube* white to cream-coloured, but usually drying reddish-brown, broadly obovoid or obovoid, shorter than or ± equal to the sepals, 1.4–1.9 mm long, 1.2–1.6 mm wide, glabrous externally and internally. *Corolla lobes* white to cream-coloured, longer than the tube, 2.3–3.2 mm long, 0.5–0.7 mm wide at base, erect in basal 1/2–2/3 and then spreading and recurved, glabrous externally, internal surface with a dense indumentum of ± terete, distinctly ornamented hairs. *Anthers* either partially exserted from the tube by at least 3/4 of their length or sometimes ± fully exserted, 0.6–0.8 mm long, apex ± emarginate. *Filaments* terete, 0.5–0.6 mm long, attached to anther just below the apex, adnate to tube just below the sinuses. *Nectary* either annular and ± lobed with deep longitudinal grooves below the sinuses, or less often clearly partite with scales 0.2–0.4 mm long, 0.2–0.3 mm wide, glabrous with the upper margins papillose. *Ovary* broadly obovoid, less often broadly ellipsoid, 0.5–0.6 mm long, 0.4–0.6 mm wide, glabrous, 5-locular, mid or sometimes dark green. *Style* pale green to straw-coloured, abruptly differentiated from ovary apex, 1.5–2.1 mm long, scabrous at least in the upper half, shortly exserted from the corolla tube, but not beyond the erect bases of the corolla lobes, discontinuous with ovarian tissue and usually arising from a depression at the ovary apex that tightly envelops, but is free from, the style base, or less often apparently arising directly from the ovary apex; stigma distinctly expanded. *Fruit* cylindrical or sometimes very narrowly ovoid, often ± curved, 3.5–4.5 mm long, 0.8–1.1 mm wide, much longer than the sepals, circular in transverse section, with a well-defined gynophore; surface glabrous, shiny, dark brown or greenish-brown, smooth (mesocarp poorly developed), with pale longitudinal lines; apex obtuse; style shed before maturity. (Figures 2B, 3B)

Diagnostic characters. Within the *S. corynocarpa* subgroup distinguished by the following character combination: leaf lamina thick, either concave adaxially or plano-convex, with 3 prominent, abaxial veins, shallowly to deeply and openly grooved between the veins; inflorescence arising from axils of regular, mature leaves, 1.0–4.5 mm long, 1–4-flowered with bracts present below the bracteoles, terminating in a bud-rudiment; flowers shortly pedicellate below the bracteoles, with a short thick pedicel to 0.5 mm long; sepals distinctly recurved distally; fruit cylindrical or sometimes very narrowly ovoid, 3.5–4.5 mm long, 0.8–1.1 mm wide.

Other specimens examined. WESTERN AUSTRALIA: Ravensthorpe–Hopetoun Rd, 3.2 km N of Hopetoun Post Office, just N of cemetery, 18 Oct. 1997, *E.A. Brown* 97/319, *P.G. Wilson & N. Lam* (CHR, NSW, NY, PERTH, UNSW); 8.6 km E of Neds Corner Rd on Cascades Rd, 1.3 km S of Cascades Rd, Reserve 36183, Oct. 1984, *M.A. Burgman* 4537 (PERTH); 130 km W of Esperance, next to Rockhole Rd, 5 Nov. 1978, *R.J. Cranfield* 1039 (CANB, PERTH); Munglinup, 7 Nov. 1978, *R.J. Cranfield* 1085 (CANB, K, NSW, PERTH); track to Lucky Bay from Thistle Cove, Cape Le Grand National Park, 7 Oct. 2003, *D.M. Crayn* 660, *A.J. Perkins & K.A. Kron* (NSW, PERTH, WFU); 5 km NE of Esperance to Israelite Bay Rd on road to Mt Ragged, 28 Nov. 1985, *D.B. Foreman* 1304 (AD, CANB, MEL, NSW, PERTH); *c.* 19 km E of Ravensthorpe on Esperance Rd, 16 Nov. 1998, *M. Hislop* 1208 (CNS, NSW, PERTH); Fitzgerald River National Park, corner Hamersley Inlet Rd and Edwards Point track, 31 Aug. 2001, *M. Hislop* 2289 (CNS, PERTH); Cape Arid National Park, Fisheries Rd, 22.1 km E of park boundary, 18 May 2002, *M. Hislop & F. Hort* MH 2617 (CNS, PERTH); behind Jerdacuttup school, Jerdacuttup, Oct. 1979, *N.S. Lander s.n.* (NSW, PERTH); 100 m SE of Mylies Beach turnoff on Hamersley Drive, Fitzgerald River National Park, W of Hopetoun, 5 Nov. 1996, *B.J. Lepschi & T.R. Lally* BJL 3182 (BRI, CANB, NSW, PERTH); 1.5 km NNW of Hellfire Bay carpark, 1.9 km E of Mt Le Grand summit, 5.9 km W of Lucky Bay campsite, Cape Le Grand National Park, 24 Nov. 2011, *A. Markey & B. Bayliss* NIB 9592 (PERTH); 20 km E of Scaddan on Styles Rd, 11 Sep. 1984, *P. van der Moezel* PGV 464 (PERTH); lower slopes of Frenchman Peak, Cape Le Grand National Park, 18 July 1982, *J.M. Powell* 1864A (CANB, L, NSW, PERTH); track to Diamonds Hill, 2 km N of Israelite Bay track, Cape Arid National Park, 30 July 1986, *J.M. Powell* 2333A (HO, NSW, PERTH); Cape Arid National Park, 1.2 km from W boundary on track to Israelite Bay, 30 July 1986, *J.M. Powell* 2336 (HO, NSW, PERTH); 15.7 km SSE from Old Ongerup Rd junction on Hamersley Drive, Fitzgerald River National Park, 2 Sep. 1986, *J.M. Powell* 2838 (HO, NSW, PERTH); base of East Mt Barren track [Fitzgerald River National Park], 18 July 2010, *C. Puente-Lelievre & E.A. Brown*

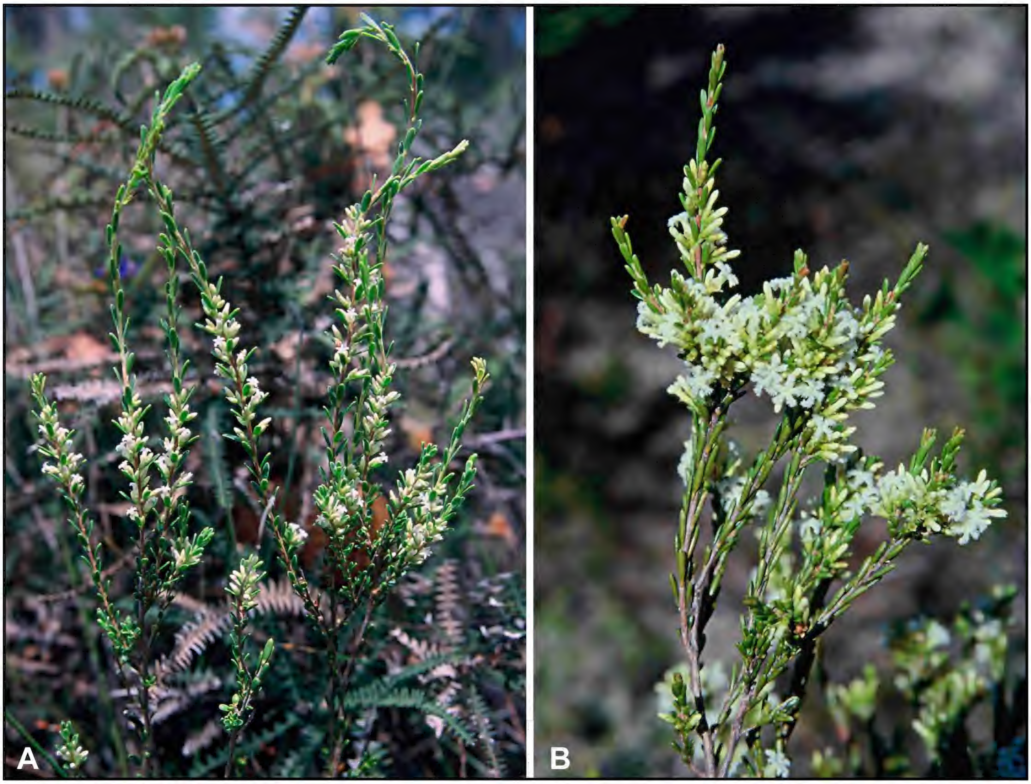

Figure 3. A – *Styphelia corynocarpa*, flowering plant *in situ.*; B – *Styphelia cylindrica*, flowering plant *in situ*. Vouchers *M. Hislop* 3085 (A), *M. Hislop* 3057 (B). Photographs by Michael Hislop.

CPL 104 (NSW, PERTH); Helms Forestry Reserve 23527 [NNW of Esperance], 28 Aug. 2011, *C.D. Turley & R.M. Hoggart* 32/811 (PERTH).

Distribution and habitat. Widely distributed in coastal and subcoastal districts from the western end of the Fitzgerald River National Park to Israelite Bay and as far inland as the Scaddan area; in the Esperance Plains and adjacent parts of the Mallee bioregions. Occurs in heath and open mallee woodland in deep sand or over laterite, quartzite or granite.

Phenology. Flowers over many months of the year but with a peak between September and December. While many flowering collections also include some fruit, the highest numbers of mature fruit are present on collections made between May and August.

Etymology. From the Latin *cylindricus* (cylindrical), a reference to the usual fruit shape.

Conservation status. Widespread and locally common over a large area. No conservation listing is recommended here.

Affinities. *Styphelia cylindrica* is a member of Group X *sensu* Puente-Lelièvre *et al.* (2016). In the published phylogeny, under the name *Leucopogon crassifolius*, it grouped very strongly (100% support) on a long branch with *S. corynocarpa*, but within a part of the tree that lacked basal support. Before the phrase name *Styphelia* sp. South Coast (J.M. Powell 3374) was added to Florabase (Western Australian Herbarium 1998–) in March 2018, this species had been erroneously treated as *Leucopogon crassifolius* Sond. since Bentham's time (1868). Refer to the notes under *Styphelia crassifolia* (Sond.) F.Muell. in Hislop and Nguyen (2022) for more details regarding this longstanding name misapplication.

The distributions of *S. cylindrica* and *S. corynocarpa* overlap in the Fitzgerald River National Park and it is with the latter species that *S. cylindrica* is most likely to be confused. Both species have a relatively tall, open habit, prominently petiolate leaves of comparable shape as well as a generally similar inflorescence and floral character. They differ most obviously in the length and posture of the sepals: 1.7–2.4 mm long and distinctly recurved distally in *S. cylindrica*, *cf.* 2.3–3.0 mm long and more or less appressed to the corolla in *S. corynocarpa*. They also differ in the shape and size of the drupe: *S. cylindrica* has a cylindrical drupe (sometimes very narrowly ovoid), 0.8–1.1 mm wide, while in *S. corynocarpa* it is narrowly obovoid or claviform and 2.3–3.0 mm wide. In addition, *Styphelia cylindrica* is unusual in Group X in having a short, thick pedicel (to 0.5 mm long) below the bracteoles, as commonly seen in the species of Group V (*sensu* Puente-Lelièvre *et al.* 2016), while in *S. corynocarpa* the flowers are quite sessile.

The other two members of the subgroup, *S. anomala* and *S. planiconvexa* have more inland distributions than those of *S. cylindrica* or *S. corynocarpa*, and both can be readily distinguished by their strictly 1-flowered inflorescences. Further differences between *S. cylindrica* and *S. planiconvexa* are given under the treatment of the latter species.

Styphelia planiconvexa Hislop, *sp. nov.*

Typus: Bendering Reserve (No 25681), 8 km E of Bendering Railway Siding, Western Australia, 13 July 1982, *J.M. Powell* 1775 (*holo*: PERTH 02953706!; *iso*: CANB 332772 *n.v.*, K *n.v.*, L *n.v.*, MEL 0642193 *n.v.*, MO *n.v.*, NSW 406318 *n.v.*, RSA *n.v.*).

Leucopogon sp. Wheatbelt (S. Murray 257), Western Australian Herbarium, in *Florabase*, https://florabase.dpaw.wa.gov.au/ [accessed 3 February 2023].

Erect *shrubs*, to *c.* 90 cm high and 70 cm wide, but usually < 70 cm high, single-stemmed at ground level with a fire-sensitive rootstock. Young *branchlets* with a moderately dense to dense indumentum of spreading, often decurved hairs, to 0.2 mm long. *Leaves* helically arranged, steeply antrorse to ± antrorse-appressed; apex usually obtuse, or occasionally subacute; base usually attenuate, or sometimes ± cuneate; petiole well-defined, 0.4–1.2 mm long, sometimes incurved, adaxial surface hairy, abaxial surface glabrous, margins glabrous or sparsely hairy; lamina narrowly elliptic, or narrowly obovate, 2.0–3.4 mm long, 0.6–1.2 mm wide, discolorous, sometimes distinctly inflexed immediately above the petiole, thick, usually plano-convex or less often concave or convex adaxially, longitudinal axis ± straight to gently incurved; adaxial surface shiny, glabrous or sparsely hairy in the lower half, the venation not evident; abaxial surface paler (often ± glaucous when young), shiny, glabrous, with 3 prominent primary veins, shallowly to deeply and openly grooved between the veins; margins often variably ciliate on young leaves, with hairs to 0.3 mm long, usually glabrous or very sparsely hairy. *Inflorescence* axillary, erect, arising from axils of regular, mature leaves; axis 0.6–1.0 mm long, 1-flowered, ± terete in lower half, distinctly compressed above the fertile node, with a sparse to moderately dense indumentum, terminating in a bud-rudiment; flowers erect, sessile. *Fertile bracts* broadly ovate to depressed-ovate, 0.4–0.7 mm long, 0.5–0.8 mm wide, subtended by 3 or 4 sterile bracts. *Bracteoles* broadly ovate, depressed-ovate to ± orbicular, 0.8–1.4 mm long, 0.8–1.3 mm wide, keeled, but usually obscurely so, obtuse; abaxial surface glabrous or rarely very shortly hairy; margins minutely ciliolate to ± glabrous. *Sepals* narrowly ovate or occasionally ovate, 1.8–3.2 mm long, 0.9–1.2 mm wide, usually obtuse, less often subacute, the apex appressed to the corolla; abaxial surface glabrous, straw-coloured or frequently partly flushed pink, the venation obscure, only the midrib usually evident; adaxial surface usually glabrous, very occasionally with a few basal hairs; margins minutely ciliolate with hairs < 0.05 mm long or ± glabrous. *Corolla tube* white, obovoid or narrowly obovoid, shorter than, equal to, or rarely slightly longer than the sepals, 1.5–2.2 mm long, 1.4–1.6 mm wide, glabrous externally and internally. *Corolla lobes* white, longer than or equal to the tube, (1.6)2.0–3.2 mm long, 0.7–0.9 mm wide at base, erect in basal 1/2–2/3 and then spreading and recurved, glabrous externally, internal surface with a dense indumentum of ± terete, lightly ornamented hairs. *Anthers* slightly exserted from the tube, but not exserted beyond the erect bases of the corolla lobes, 0.5–1.0 mm long, apex shallowly emarginate. *Filaments* terete, 0.5–0.8 mm long, attached to the anther at least 3/4 above anther base, usually just below the apex, adnate to the tube just below the sinuses. *Nectary* very thick, either annular and lobed with deep longitudinal grooves below the sinuses, or clearly partite with scales 0.2–0.3 mm long, 0.2–0.3 mm wide, glabrous, the margins not papillose. *Ovary* ellipsoid to obovoid, 0.5–0.6 mm long, 0.3–0.5 mm wide, glabrous, 5-locular, straw-coloured to pale brown. *Style* pink or red, well-differentiated from ovary apex, 1.8–2.7 mm long, slightly scabrous in upper half, smooth below, exserted from the corolla tube but not beyond the erect bases of the corolla lobes, discontinuous with ovarian tissue, apparently arising directly from the ovary apex; stigma slightly expanded. *Fruit* narrowly ellipsoid or oblongoid, 2.7–3.3 mm long, 1.0–1.2 mm wide, usually longer than or sometimes ± equal to the sepals, circular in transverse section, with a well-defined gynophore; surface glabrous, shiny, dark green or greenish-brown, smooth or with indistinct longitudinal ribs (mesocarp poorly developed); apex obtuse to subacute; style shed before maturity. (Figures 4, 5, 6)

Diagnostic characters. Within the *S. corynocarpa* subgroup, distinguished by the following character combination: leaf lamina thick, usually plano-convex or, less often, concave or convex adaxially, with 3 prominent, abaxial veins, shallowly to deeply and openly grooved between the veins; inflorescence arising from the axils of regular, mature leaves, 0.6–1.0 mm long, strictly 1-flowered with bracts present below the bracteoles, terminating in a bud-rudiment; flowers sessile below the bracteoles; sepals appressed to the corolla; fruit narrowly ellipsoid or oblongoid, 2.7–3.3 mm long, 1.0–1.2 mm wide.

Other specimens examined. WESTERN AUSTRALIA: Cascades Rd, 13 km NW of Rolland Rd [NW of Cascade], 21 Apr. 2013, *W.R. Archer* 21041310 (PERTH); Bendering Nature Reserve, [NE of Kondinin], 7 Oct. 2009, *R.L. Barrett & M.D. Barrett* RLB 5916 (CNS, CANB, PERTH); Beynon Rd along the edge of Breakaway Ridge Reserve, Newdegate, 1 Sep. 2010, *G. Byrne* 3925 (CNS, PERTH); UCL Lake King townsite, site 3, 17 Nov. 2006, *A.M. Coates* AC 5843 (PERTH); Pingaring–Varley Rd North, 30 Sep. 2004, *A.S. George* 17668 *& E.G.H. Oliver* (PERTH); remnant vegetation W side of Lake Varley–Hyden Rd, 43 km S of Hyden, 28 June 1999, *M. Hislop* 1316 (CANB, NSW, PERTH); Southern Cross–Forrestania Rd, 53 km S of Burbridge Rd, 8 Aug. 2000, *M. Hislop* 2106 (PERTH); Antonio Rd, 3.9 km W of Ivey Rd, S of Bodallin, 25 July 2005, *M. Hislop* 3482 (CNS, K, PERTH); E outskirts of Lake King, 25 July 2006, *M. Hislop* 3616 (CANB, CNS, K, MEL, PERTH); surrounds of gravel extraction site, Floater Rd, 7 km N of Woodenup Rd, N of Ravensthorpe, 27 June 2007, *M. Hislop* 3715 (CNS, NSW, PERTH); Lake King–Cascades Rd, 29.7 km S of Norseman road, 15 May 2002, *M. Hislop & F. Hort* MH 2595 (CNS, PERTH); Boolanelling Nature Reserve, Copestakes Rd, [N of Corrigin], 4 Aug. 2009, *F. Hort, J. Hort & B. Hort* FH 3430 (CANB, K, MEL, PERTH); North Karlgarin Nature Reserve, Bendering Reserve Rd, NE of Kondinin, 4 July 2007, *G.J. & B.J. Keighery* 1185 (CANB, CNS, MEL, NSW, PERTH); 2.3 km S along Whittington Rd from Middleton Rd, S of Corrigin, 25 May 2000, *K. Kershaw* 2095 (CNS, MEL, PERTH); on track to Hatters Hill from Digger

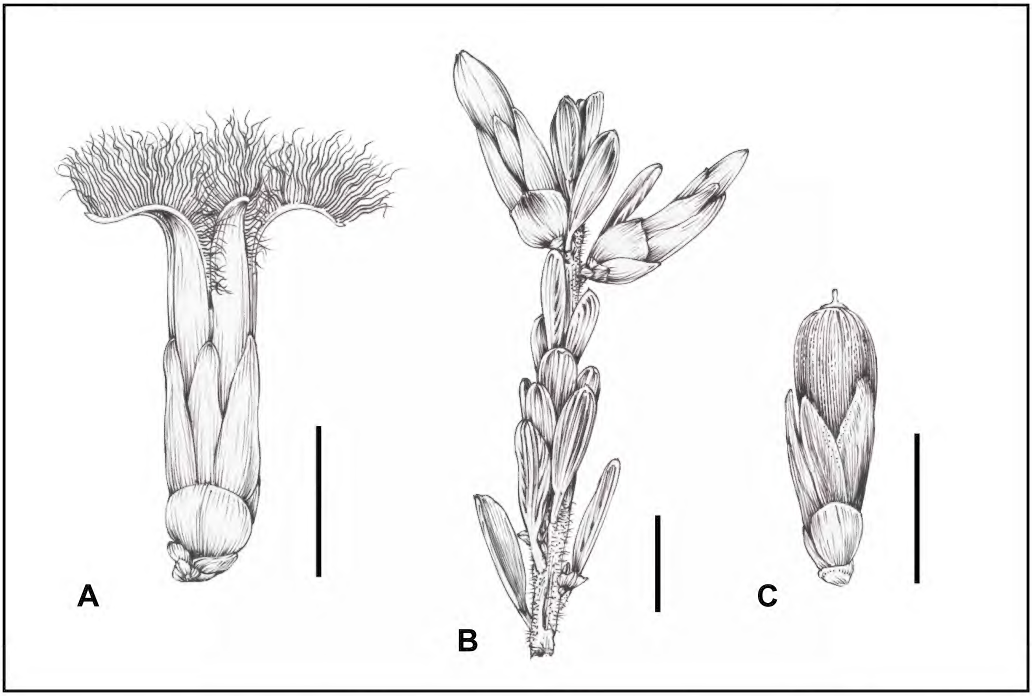

Figure 4. *Styphelia planiconvexa*. A – flowering inflorescence; B – flowering branchlet, showing inflorescences arising from leaf axils; C – fruit. Scale bars = 2 mm. Vouchers *M. Hislop* 1316 (A, B), *R.L. Barrett & M.D. Barrett* RLB 5916 (C). Drawings by Hung Ky Nguyen.

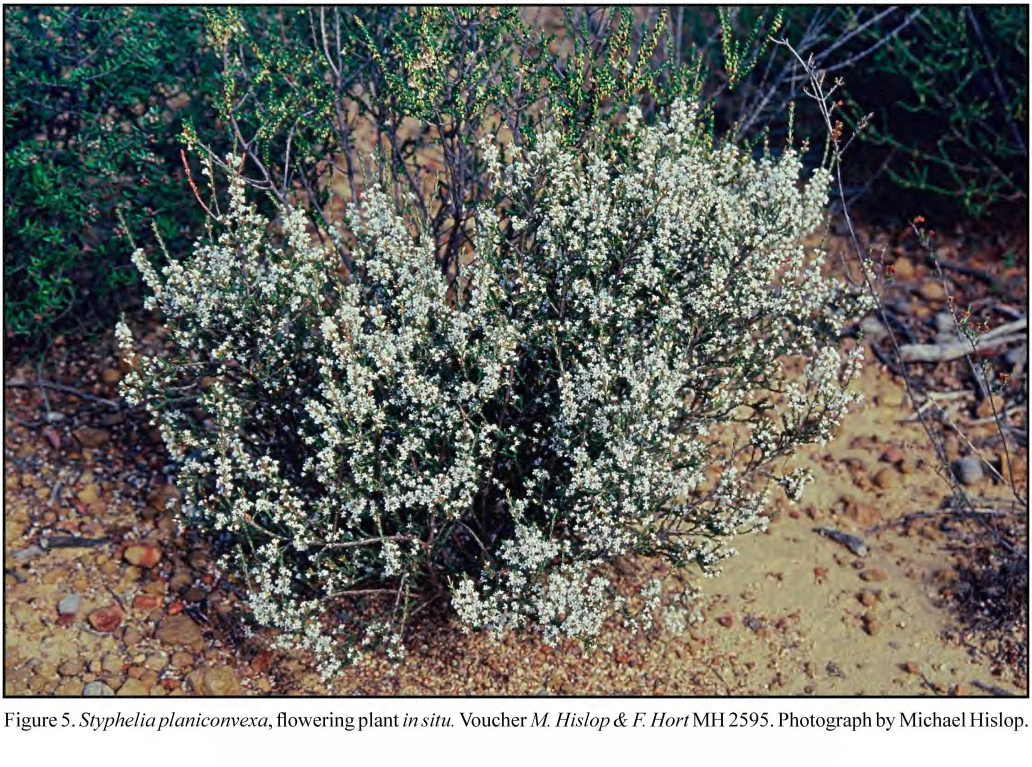

Figure 5. *Styphelia planiconvexa*, flowering plant *in situ.* Voucher *M. Hislop & F. Hort* MH 2595. Photograph by Michael Hislop.

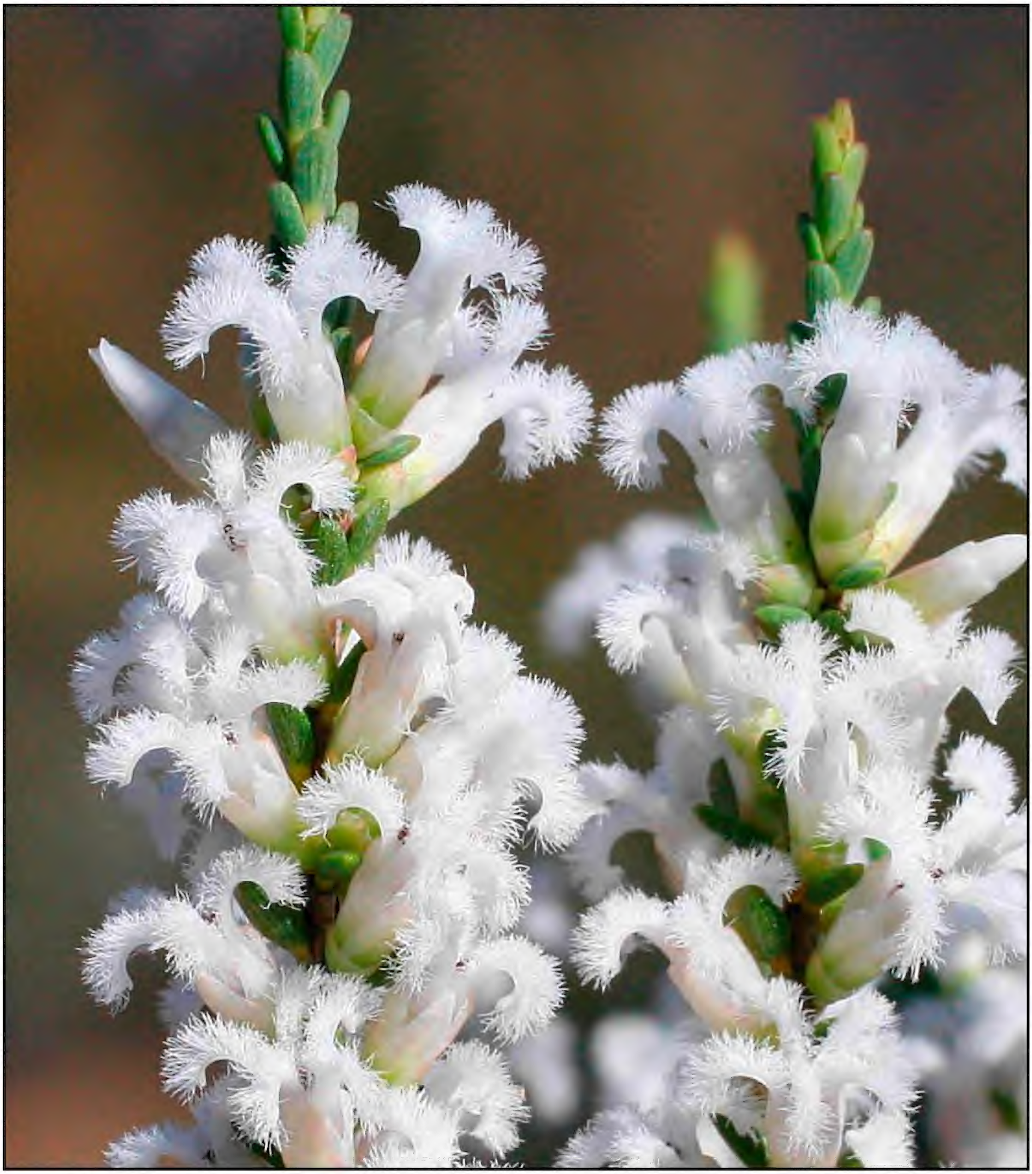

Figure 6. *Styphelia planiconvexa* flowering branchlet *in situ.* Voucher *G. Byrne* 2065. Photograph by Geoff Byrne.

Rocks, 22 Aug. 2001, *K. Kershaw & M. Golding* KK 2277 (NSW, PERTH); 19.7 km ENE of East Hyden Bin Rd on Hyden–Lake King Rd, 20 km ENE of Hyden, 11 Aug. 1996, *T.R. Lally & B.J. Lepschi* TRL 1144 (PERTH); 13 km S of Mt Glasse, Bremer Range, 21 July 1979, *K.R. Newbey* 5390 (PERTH); Borden–Pingrup Rd, 39.3 km S of junction with Katanning road, 6 Aug. 1986, *J.M. Powell* 2452A (HO, K, NSW, PERTH); Hartleys Reserve (S boundary), 14.3 km S of Corrigin on Corrigin South Rd, 15 July 1999, *L.W. Sage, J.P. Pigott & E.B. Pigott* LWS 1539 (CNS, K, MEL, PERTH).

Distribution and habitat. Widely distributed in the southern wheatbelt south of Great Eastern Highway and eastwards into uncleared land beyond the agricultural zone. Extends from south-east of Quairading eastwards to north-west of Cascade, and from south of Bodallin in the north to north of Borden in the south; mostly in the Avon Wheatbelt and Mallee bioregions with more limited occurrences in the far west of the Coolgardie and far north of the Esperance Plains bioregions.

Mostly grows in sand or sandy loam soils over laterite, less often in deep sand. Associated vegetation is heath or open mallee woodland.

Phenology. Plants may flower over many months of the year, at least between April and September, depending on the rainfall pattern during the period late summer to early winter. Fruiting collections have been made between September and November but could certainly be expected outside this period given the extended flowering time.

Etymology. From the Latin *planus* (flat) and *convexus* (convex), a reference to the usual transverse section of the leaves.

Conservation status. A widespread and locally common species, which is known to occur in many nature reserves.

Affinities. Although not included in the phylogeny of Puente-Lelièvre *et al.* (2016), *S. planiconvexa* shares many critical morphological attributes with *S. corynocarpa* and *S. cylindrica* and they are considered likely to be its closest relatives.

Before the name *Leucopogon* sp. Wheatbelt (S. Murray 257) was added to Florabase in September of 1999 the species had mostly been referred to *Leucopogon crassifolia auct. non* Sond. (i.e. *S. cylindrica* as described above) or informally to the 'Wheatbelt variant' of *S. leptantha* (Benth.) F.Muell. Jocelyn Powell, a prominent researcher in the taxonomy of the epacrids in the 1980s and 1990s, recognised that it was a distinct taxon and sometimes referred to it as *L.* sp. *aff. crassifolia* on her collection labels.

Although *S. planiconvexa* has frequently been misidentified as *S. cylindrica* there are a number of easily interpreted differences between the two. The most obvious pertain to the sepals (appressed to the corolla in *S. planiconvexa*, *cf.* recurved in the upper half in *S. cylindrica*) and the inflorescence (very short, 0.6–1.0 mm long and strictly 1-flowered in *S. planiconvexa*, *cf.* 1.0–4.5 mm long and 1–4-flowered in *S. cylindrica*). The fruit also differ: being narrowly ellipsoid or oblongoid, 2.7–3.3 mm long, 1.0–1.2 mm wide, and always straight in *S. planiconvexa cf.* cylindrical or sometimes very narrowly ovoid, 3.5–4.5 mm long, 0.8–1.1 mm wide, and often ± curved in *S. cylindrica*. The short, thick pedicel (to 0.5 mm long) of *S. cylindrica* is also lacking in *S. planoconvexa*, where the flowers are sessile below the bracteoles.

Although *S. planiconvexa* had been previously referred to as the 'Wheatbelt variant' of *S. leptantha* (Benth.) F.Muell., the two species are only superficially similar. *Styphelia leptantha* is a confirmed member of the *S. pendula* group (or Group V) from the Geraldton Sandplains and far north of the Swan Coastal Plains bioregions. It is somewhat anomalous within that group because of its adaxially concave leaves and in having the point of attachment of filament to anther rather higher than is usual in the group, about 3/4 above anther base. In respect to these characters, *S. leptantha* is similar to species from Group X, although the very dark ovary is typical of the *S. pendula* group, refer interim key to *Styphelia* groups in Western Australia (Hislop 2021: 29–31). While *S. leptantha* shares with

S. planiconvexa similarly shaped, non-mucronate leaves and an erect inflorescence, the two are readily distinguished. Relative to the leaves of *S. planiconvexa*, those of *S. leptantha* are always adaxially concave (rather than usually planoconvex) with the wider leaves at least 1.5 mm wide (*cf.* to 1.2 mm). In terms of floral differences, *S. leptantha* has the corolla tube always much longer than the sepals and the stigma greatly expanded at anthesis, whereas in *S. planiconvexa* the tube is usually shorter than, or more or less equal to, the tube (rarely slightly longer) and the stigma only slightly expanded. The fruit of the two species is also very different: strongly angular in transverse section in *S. leptantha*, circular in *S. planiconvexa*.

Styphelia planiconvexa is the only species within the subgroup to have a red or pink style and to frequently have pink-flushed sepals; the other three species having straw-coloured or greenish styles and straw-coloured sepals.

Acknowledgements

I would like to thank Hung Ky Nguyen for the fine illustrations and Geoff and Ruth Byrne for the beautiful image of *S. planiconvexa*.

References

Bentham, G. (1868). *Flora Australiensis*. Vol. 4. (Reeve & Co.: London.)

Department of Climate Change, Energy, the Environment and Water (2021). *Australia's bioregions*. https://www.dcceew.gov.au/environment/land/nrs/science/ibra#ibra [accessed 3 February 2023].

Hislop, M. (2021). Interim key to, and composition of, species groups in Western Australian *Styphelia*. *Nuytsia* 32: 29–37.

Hislop, M. & Nguyen, H.K. (2022). A taxonomic review of the *Styphelia tamminensis* subgroup (Ericaceae: Epacridoideae: Styphelieae). *Nuytsia* 33: 275–320.

Powell, J.M., Morrison, D.A., Gadek, P.A., Crayn, D.M. & Quinn, C.J. (1997). Relationships and generic concepts within Styphelieae (Epacridaceae). *Australian Systematic Botany* 10: 15–29.

Puente-Lelièvre, C., Hislop, M., Harrington, M., Brown, E.A., Kuzmina, M. & Crayn, D.M. (2016). A five-marker molecular phylogeny of the Styphelieae (Epacridoideae, Ericaceae) supports a broad concept of *Styphelia*. *Australian Systematic Botany* 28: 368−387.

State of Western Australia (2022). Biodiversity Conservation (Listing of Native Species) (Flora) Order 2022. Western Australian Government Gazette 2022(144): 4763–4768. https://www.legislation.wa.gov.au/legislation/statutes.nsf/gazettes2022.html [accessed 3 February 2023].

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au/ [accessed 3 February 2023].

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/ *Nuytsia* 34: 157–178
https://doi.org/10.58828/nuy01057 Published online 20 July 2023

Ferdinand Mueller in Western Australia in 1877, with notes on his later contributions to the Western Australian flora

John Leslie Dowe

Australian Tropical Herbarium, James Cook University, Smithfield, Queensland 4878
Email: john.dowe@jcu.edu.au

Abstract

Dowe, J.L. Ferdinand Mueller in Western Australia in 1877, with notes on his later contributions to the Western Australian flora. *Nuytsia* 34: 157–178 (2023). Baron Ferdinand von Mueller, Australia's most productive botanist of the mid–late nineteenth century, was especially enamoured with the flora of Western Australia, and wrote about its 'marvellous exuberance', 'typic singularity' and 'endemism'. He botanised in Western Australia on three occasions: in 1856 in the Sturt Creek area during Augustus Gregory's North Australian Exploring Expedition; in 1867 in the Porongurup Range and Stirling Range and around Albany; and in 1877 with excursions from Champion Bay to Shark Bay and from Perth to Albany. Although he considered that most of Australia's plant taxa had been described by the late 1870s, he remained attentive for novelties, especially those that were rare or from remote, under-botanised areas, especially in Western Australia. Many of Mueller's later publications consolidated aspects of nomenclature, systematics, biogeography, economics, horticulture and utilisation of the flora of Western Australia.

Introduction

Ferdinand von Mueller (1825–1896) was Australia's most productive and prominent botanist of the latter half of the nineteenth century. As government botanist for the colony of Victoria 1853–96, his ambition was to elucidate the flora for the entire Australian continent. However, his most productive taxonomy involved two states (then colonies), Victoria and Western Australia. As government botanist for Victoria this was an expected outcome for that colony as he was based in Melbourne. For Western Australia, particularly the south-west region, it was a matter of deep interest, astonishment and intrigue as the flora there was of a significantly different character and composition compared to much of the rest of the continent (Mueller 1886a). As early as 1867, Mueller (1867: 10) articulated the botanically unique aspects of the south-western parts of Western Australia, writing that 'no part of Australia has the marked peculiarities of its vegetation so strongly expressed, and no part of this great country produces so rich an assemblage of species within a limited area, as the remotest south-western portion of the continent'. Later in his career and summarising botanical endeavours in Western Australia, Mueller (1896a: 195) expressed that the flora exhibited 'a marvellous exuberance of plants, different in species, and often gay or odd in aspect', and reiterated that the greatest proportion of Australia's endemic plants occurred 'within a triangle formed by a line of demarcation drawn from the south of Sharks Bay to the west of the Great Bight; and within this space are chiefly located those species which are exclusively restricted to the West Australian territory'. This area was subsequently recognised as the South-western Botanical Province (Beard 1980), a designation that remains current.

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

The first assessment of Mueller's work on the Western Australia flora was provided by Diels (1906: 56) writing that Mueller's 'receptive sense strongly felt the aesthetic peculiarity of this flora. Its creations filled him with devotion … there is something touching about reading the words that close his last short description of Western Australian vegetation; they seem like saying goodbye to a circle of friends you have grown fond of'. Diels work was in German and two English translations are available, partly by Carr in 1981 and fully by Grieve *et al.* in 2007 (see Diels (1981) and Diels (2007) respectively).

Mueller (1879: 2), on botanising in Western Australia, wrote that he 'had only on three occasions the opportunity of traversing portions of the vast extent of West Australia, and then only for a few weeks each time'. The first, in 1856, was during Augustus Gregory's North Australian Exploring Expedition to which Mueller was appointed botanist (Cohn 1996; Dowe & Schweizer 2022). This expedition was sponsored by the British Government and the Royal Geographical Society, London, and was undertaken by Mueller after obtaining leave of absence from his position of government botanist of Victoria (Cohn 1996). The expedition sailed from Sydney to arrive at Victoria River (18 July–15 Sept. 1855) before exploring much of the Victoria River catchment and nearby areas (15 Sept. 1855–21 June 1856) and then travelling eastward through inland northern Australia to reach Brisbane (21 June–Dec. 1856) (Gregory 1857, 1858). The expedition's movement into Western Australia was only for a short distance when they travelled for about 300 km from the Northern Territory border into Western Australia whilst exploring Sturt Creek to as far inland as the permanent brackish Lake Gregory of which Sturt Creek is the primary source mainly fed by monsoonal rain events. The lake has no outlets. Gregory (1858: 46) wrote that the exploring party, for this excursion, included himself, as well as 'Mr. H. Gregory [brother Henry Churcham Gregory], Dr Mueller, and Charles Dean [stockman]'. On 21 February, 1856, Gregory (1858: 53) wrote that 'according to our longitude by account we have this day passed the boundary of Western Australia, which is the 129th meridian'. Soon after reaching Lake Gregory on about 5 March, the expedition retraced Sturt Creek and exited Western Australia by 20 March. Mueller returned from the North Australian Exploring Expedition with many thousands of specimens (Mueller 1856, 1857a–c), but it is not possible to positively identify those that were collected in Western Australia, although those labelled with 'Sturt's Creek' are obvious contenders (see AVH 2022). Although the headwater of Sturt Creek is in the Northern Territory, about 70% of its length is in Western Australia. Geographic names introduced by Gregory for places in Western Australia include Sturt [as Sturt's] Creek (22 Feb., for explorer Charles Napier Sturt), Mt Wittenoom (22 Feb., most likely for John Burdett Wittenoom, clergyman and educator in Perth), Mt Mueller (2 Mar., for Ferdinand Mueller), Mt Wilson (5 Mar., for expedition geologist James Spottiswood Wilson) and Denison Plains (17 Mar., for William Denison, Governor of New South Wales 1847–55, to whom Gregory reported).

Mueller's second visit to Western Australia was in 1867 when he departed Melbourne on 28 September for King George Sound,[1] and arrived there about 5 October. It was reported that 'his state of health rendered a brief absence from the colony necessary, and it is stated that he was obliged to take this step so suddenly that he had no time to obtain the necessary permission from the minister in charge of his department'.[2] From Albany, he travelled to Porongurup Range, Stirling Range and intermediate and nearby locations. He departed King George Sound for Melbourne on 9 November, arriving there on 14 November.[3] In the field, Mueller was accompanied by George Maxwell, writing to Bentham that 'I took Mr Maxwell along with me and camped out a good deal'.[4] George Maxwell (1804–1880) had been collecting botanical specimens in Western Australia since the 1840s and worked with collectors such as James Drummond, William Harvey and Augustus Oldfield (George 2009; Henderson 2011). Although there is only limited surviving correspondence between Mueller and Maxwell, they evidently worked productively together. In an obituary, Mueller (1880: 433) wrote that 'encouraged by myself he [Maxwell] undertook several extensive journeys over then untrodden ground, eastward as far as the Great Bight, and thus found many new plants, and enabled us to extend the known limits of the range of many rare species, as recorded in the Flora Australiensis'. Maxwell's productivity makes him one of the most significant botanical collectors active in Western Australia during the nineteenth-century. In regard to other field assistance provided to Mueller, he noted in a letter to Western Australian colonial secretary Frederick Barlee that 'Sir Alexander Campbell has been most kind to me, and so were the few settlers, which in my line of travel I could visit'.[5] At the time, Sir Alexander Thomas Cockburn-Campbell was Resident Magistrate, Deputy Treasurer and Sub-collector of Customs at Albany, positions he held from 1861 until his death in 1871. Mueller's recorded collection localities include King George Sound, Mondurup Peak, Stirling Range and upper Kalgan River.

---

[1] *The Empire* (Sydney). Melbourne. 4 Oct. 1867, p. 4.

[2] *The Herald* (Melbourne). No title. 1 Oct. 1867, p. 2.

[3] *The Leader* (Melbourne). Shipping. 16 Nov. 1867, p. 14.

[4] F. Mueller to George Bentham, 3 Nov. 1867. Home *et al.* (2023+).

Mueller's third visit to Western Australia was during October–December 1877, and is the primary subject of this paper. With regard to previous research on this visit, only broad and otherwise unconnected aspects have been published and it is an event in Mueller's career that required further examination (pers. comm., Arthur Lucas, Mueller Correspondence Project). This work aims to provide an account of that excursion, examining his itinerary, taxonomic results and personal interactions.

Ferdinand Mueller's interest in the Western Australian flora

At the age of 52 years, Mueller travelled to Western Australia in October 1877, with a number of specific tasks in mind: to visit Shark Bay 'to see how far there the southern and the tropical forms of plants are meeting',[6] and to improve his well-being, 'to re-establish my fluctuating health, which suffered much under the cruel and undeserved oppressions, to which I was a victim since several years'.[7] In respect to potential botanical 'discoveries' he was restrained, writing that 'few actual novelties could be expected to occur after the longer searches made by Drummond and others' (Mueller 1878a: 151), in reference to the plant collections made in Western Australia by collectors since the commencement of European exploration.

Although there is no evidence that Mueller undertook the 1877 excursions with any prior commitment of support of the Western Australian government, he appears, whilst there, to have been encouraged to complete a report on the forest resources of the colony. On his departure in late December, he wrote to Western Australian colonial secretary Roger Goldsworthy: 'After my return to Melbourne, and when again at the command of all my working material, I shall commence to furnish some data on the scientific aspect of the timber resources of your colony and on some other objects of vegetable wealth of this country, by which means I trust to offer some slight tribute in return for the unexpected advantages, which I have enjoyed through the generous action of the West Australian Government'.[8] More on this, and other results and publications, is discussed below.

Although the Western Australian Government appears not to have initially endorsed Mueller's trip to Western Australia, he nevertheless received support in the form of transport (horses) and guides during all the excursions. It has not been possible to determine what, if any, direct involvement the Western Australian government had in initially supporting Mueller's visit to Western Australia in 1877. It appears that he undertook the Champion Bay to Shark Bay excursion on his own volition but with personal support from government surveyor and friend John Forrest. However, the excursion from Perth to Albany appears to have had some official support by the Western Australian government.[9] For this excursion, Mueller was granted an extension to his leave.[10] Mueller (1879: 2) noted that the excursion was 'carried out under special facilities, liberally afforded by the West Australian Government'. Overall, co-ordination of Mueller's field travels was overseen by Forrest who had connections with other government services and facilitated land and sea transport, horses, personnel and accommodation. Mueller noted that this assistance was essential to the success of the excursion. In a summarising letter to Western Australian colonial secretary Roger Goldsworthy, Mueller wrote: 'it is my pleasurable duty, to express my deep gratitude to your government for the interest evinced in my researches and the great support given to my recent travels in your colony'.[11] He went on to list those officials who contributed to the success of the excursions. The persons involved are discussed below when relevant to Mueller's itinerary.

---

[5] F. Mueller to Frederick Barlee, 28 Oct. 1867. Home *et al.* (2023+).

[6] F. Mueller to George Bentham, 10 Oct. 1877. Home *et al.* (2023+).

[7] F. Mueller to Joseph Hooker, 5 Oct. 1877. Home *et al.* (2023+).

[8] F. Mueller to Roger Goldsworthy, 27 Dec. 1877. Home *et al.* (2023+).

By the late 1870s, Mueller's taxonomic productivity and the description of new taxa had been waning and by the time he undertook the trip to Western Australia in 1877 he was primarily dealing with consolidation of the floristic research thus far achieved for Australia. A graph illustrating Mueller's descriptions of new taxa over time is presented in Figure 1, and illustrates the decline in novelties following very active taxonomy in the early years of his career. His contribution to *Flora Australiensis* had come to a conclusion with publication of the seventh and last volume in 1878 (Bentham 1878). The number of undescribed taxa available to Mueller throughout Australia was declining as a result of continent-wide settlement. Although Mueller reiterated the lack of potential of new discoveries in Western Australia on a number of occasions, he nevertheless reaffirmed the great floristic diversity in Western Australia by describing many species in the latter decades of his life, some based on his own collections as well as those, for example, by John and Alexander Forrest (Mueller 1881, 1883), H.S. King (Mueller 1886b), J.D. Batt (Short 1997) and resident amateur collectors including many women (Archer & Maroske 1996; George 2009; Maroske & Vaughan 2014). He remained active in soliciting interested persons to collect specimens on his behalf, especially in remote areas. One newspaper, in 1883, reported on Mueller's appeals to settlers in Western Australia, in which he urged 'inland and northern and far eastern settlers to induce the natives to bring, in baskets, specimens of all sorts of plants, to be dried at the stations and forwarded to me by post … perhaps I may not live many years to carry on my investigations and I should like so much to give the finishing stroke for the elaboration of the rich and varied flora of Western Australia before I pass away'.[12] In a later report Mueller was specific in the locations that were of interest to him. He wrote in 1885: 'I want, particularly, plants from near the sources of the Murchison River, also from far east of York, as well as from Eucla, Fraser Range and other distant eastern localities in your vast colonial territory'.[13] In respect to particular plants, Mueller wrote in 1889: 'Of about 50 W.A. acacias the fruits are not yet known; sprigs therefore of these kinds of plants would be very welcome, as those would help gradually

---

[9] F. Mueller to Graham Berry, 12 May 1878. (Home *et al.* 2023+).

[10] Roger Goldsworthy to Graham Berry, L77/12831, unit 1011, VPRS 3991/P inward registered correspondence, VA 475 Chief Secretary's Department, Public Record Office, Victoria. Post Office Telegraphs. From Perth: Western Australia, 21/11/77.

[11] F. Mueller to Roger Goldsworthy, 27 Dec. 1877. Home *et al.* (2023+).

[12] *The West Australian* (Perth). Occasional notes. 24 July 1883, p. 2.

[13] *The Inquirer and Commercial News* (Perth). Letters to the editor. 17 June 1885, p. 5.

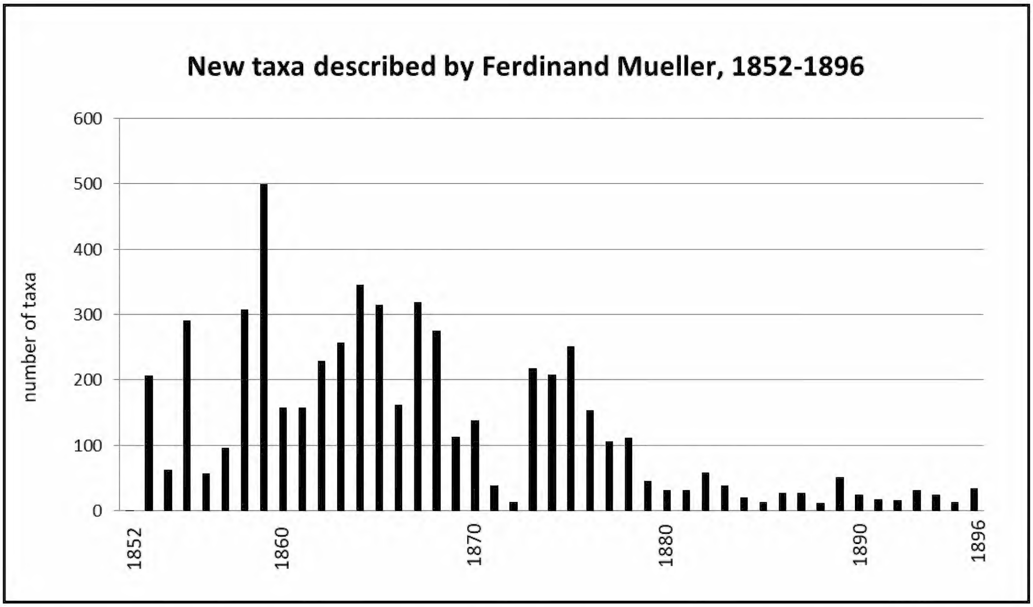

Figure 1. Timeline of new taxa described by Ferdinand Mueller, 1852–1896. Lists of taxa with author as "F.Muell." were generated from the *International Plant Names Index* based on all years between 1852 and 1896, accessed Dec. 2022. New combinations were deleted from the lists.

to complete the atlas of acacias, of which 130 plants have already appeared'.[14] In his *Iconography of Australian species of Acacia and cognate genera,* Mueller (1887–1888) included 36 species from Western Australia, but noted that 'no plant has been admitted into these pages, of which the material for detail-analysis was not fully extant', thus his interest in obtaining full material of those Western Australian species yet to be illustrated.

An event demonstrating Mueller's single-minded interest in acquiring specimens of Western Australian plants was related by the English artist Marianne North, who visited Australia in 1880-1881. North travelled extensively in southern Queensland, New South Wales, Victoria, Western Australia and Tasmania, producing 80 paintings (depicting *c.* 200 spp.) of Australian plants mostly in habitat, and which are now on permanent exhibition in the Marianne North Gallery at Royal Botanic Gardens Kew, U.K. (Dowe 2020). She completed 22 paintings of Western Australian plants. In her book *Recollections of a Happy Life being the Autobiography of Marianne North* (North 1892), she wrote that when she visited Mueller in Melbourne after her visit to Western Australia, she showed him her paintings of which Mueller, in a letter to Joseph Hooker, wrote: 'This evening I saw Miss North after her voyage to West Australia, and bid her Adieu, as she will start for Tasmania in a few days. Her paintings of W.A. vegetation are grand. I particularly admired your fathers *Euc. macrocarpa*; you probably have this brillant [sic] species at Kew, as I sent seeds repeatedly'.[15]

It was during their meeting that North also showed Mueller specimens of flowers of *Eucalyptus macrocarpa* Hook., collected by her in Western Australia at Toodyay. She wrote: 'Baron von Mueller was excited over my paintings of the *Nuytsia* [*Nuytsia floribunda* (Labill.) R.Br. ex G.Don] and the *Eucalyptus macrocarpa*, which he had named [correctly W.Hooker], but had never seen in flower.

---

[14] *The West Australian* (Perth). The flora of Western Australia. 2 July 1889, p. 3.

[15] F. Mueller to Joseph Hooker, 15 Jan. 1881. Home *et al.* (2023+).

When I showed him the bud with its white extinguisher cap tied over it, which I was saving for Kew, he said, "Fair lady, you permit I take that" and calmly pocketed it!'. This specimen [MEL1612940] is held in the herbarium of Royal Botanic Gardens Victoria (Maroske 2014).

After 1877, new taxa from Western Australia were published by Mueller in a broad range of publications, including the final volumes of *Fragmenta phytographiae Australiae*, *Southern Science Record*, the *Chemist and Druggist with Australasian supplement*, *Victorian Naturalist* and in his account of the collections made by King (Mueller 1886b). As taxonomic novelties were less forthcoming in Australia, Mueller paid particular attention to the floras of New Guinea and the Pacific islands, for which he described many new species through the 1880s and early 1890s (see Churchill *et al.* 1978).

In addition to material for taxonomic work, Mueller remained alert for species that were of horticultural potential. Whilst in the Shark Bay area he hoped to collect seeds of *Verticordia oculata* Meisn., intending to propagate the species and to send living plants to Kew (Mueller 1878a). Mueller described the species as 'the most beautiful plant in its own delicacy of all Australia'[16] and 'a princess among Australian flowers' (Mueller 1896a: 197). However, obtaining seeds of *V. oculata* proved difficult and propagation even more so, and to cultivate the species was to be Mueller's 'greatest triumph (gained by me) in ornamental culture'.[17]

Mueller persisted with this aspiration, writing in 1889 to Dr Charles Bolton Elliott of Champion Bay: 'For a series of years, dear Dr Elliott, I have vainly endeavoured to obtain living plants or germinable seeds of the true Verticordias from the Sandplains between the Geraldine Mine [north of Northampton] and the Greenough River [east of Geraldton]. As this tract is within your official area, you might likely know some people there who about Easter would send you fresh a few branches of each of these two Verticordias, wrapped up at once. If these were forwarded speedly [sic] by post from your place enveloped in some air and water tight substance they would likely remain suple [sic] and retain sufficient sap so that I might make the first experiment of getting these two most beautiful plants of W.A. to grow from cuttings under a bell-glass with bottom heat here. Perhaps I could be supplied also with shrivelled flowers which about Easter ought to have formed their tiny seeds within'.[18] Dr Charles Bolton Elliott (*c.*1851–1904) was government medical and quarantine officer in Geraldton.[19]

Mueller's drive to account for Australia's floristic diversity continued despite the personally perceived and real obstacles that he was experiencing. Mueller's reference to his declining health and grim emotional circumstances were included in a number of proposals as to why he undertook the Western Australian excursions in both 1867 and 1877. One of the impacts on his health was his controversial dismissal as director of the Melbourne botanic gardens in 1873 (Cohn & Maroske 1996), an outcome that he felt was unjust and that became a persistent grievance (Hay 2021). He remained embittered by the actions of those public servants and nurserymen who 'conspired' to remove him as director, although he remained, after dismissal as director of the botanical gardens, as government botanist at an unchanged salary. Another significant impact was the death in 1876 (11 Feb.) of Dr Eduard Wehl, the husband of Mueller's sister Clara and Mueller's brother-in-law. Eduard's death left Clara in a precarious position as eight of their fifteen children were then under the age of 14 years, with the youngest not quite three months old (Dowe *et al.* 2020). Mueller visited Clara in South Australia in

---

[16] F. Mueller to William Thiselton-Dyer, 19 Aug. 1892. Home *et al.* (2023+).

[17] F. Mueller to William Thiselton-Dyer, 28 Aug. 1889. Home *et al.* (2023+).

[18] *The West Australian* (Perth). The flora of Western Australia. 2 July 1889, p. 3.

[19] *The Geraldton Express and Murchison and Yalgo Goldfields Chronicler*. Death of Dr. Elliott. 13 May 1904, p. 7.

February 1876 to assist with Eduard's estate and to put in place some financial support for her and her family. He later provided money for the education of some of the children,[20] as well as including them as beneficiaries in his Will.[21]

Mueller's itinerary and outcomes in Western Australia, October to December 1877

Mueller's Western Australian itinerary presented here was formulated mainly on correspondence accessed via the *Correspondence of Ferdinand von Mueller* (Home *et al.* 2023+), newspaper reports and shipping notifications, mostly accessed through the Trove newspaper search facility (Trove 2022). There were miss-matches of dates between some reports and in those instances the timetable is determined on the most probable outcome. There are also significant gaps in the available data and caution is necessary in interpreting some itinerary dates and events.

Mueller departed Williamstown (Melbourne) on R.M.S.S. *Siam* on the afternoon of 4 October 1877 bound for King George's Sound via Glenelg (Adelaide).[22] On arrival at Glenelg on the morning of 6 October,[23] he was taken to *Hotel Europe* (Grenfell Street, Adelaide) where the German Club, chaired by his friend Friedrich Krichauff, provided an address of welcome in which they spoke of his attainments in botanical science and his proposed visit to Western Australia to further his research.[24] Mueller departed Glenelg on the evening of the same day on R.M.S.S. *Siam*.[25]

Mueller arrived in Albany on 10 October.[26] The following morning (11 Oct.) he boarded S.S. *Rob Roy* and sailed for Perth,[27] via Torbay, Busselton and Bunbury, and arrived at Fremantle on 15 October.[28] It was reported that S.S. *Rob Roy* had 'made an unusually long passage, having been compelled, by stress of weather, to anchor under West Cape Howe, for about forty-two hours'.[29] From Fremantle, Mueller was taken to Perth by Mr. John Forrest, 'by whom he was introduced to many of the citizens on his arrival'.[30]

Mueller reboarded the S.S. *Rob Roy* on the following day (16 Oct.), and sailed to Champion Bay.[31] It was reported that 'the object of his visit is to determine the northerly limits of the flora of this colony, for which purpose he has started for the Upper Murchison and Sharks Bay. The Baron is accompanied by a mounted trooper and a native constable, placed at his disposal by the local Government'.[32] The date and time of his arrival at Champion Bay are not known, nor are his immediate movements. The mounted trooper was Corporal Oliver Llewellyn Jones (1848–1933) (George 2009).[33] Jones accompanied Mueller on his travels to Shark Bay and back to Champion Bay. It appears that Jones remained at Champion Bay after Mueller's departure for Perth. Jones went on to collect for Mueller including type specimens from Gascoyne River (for example, *Acacia sclerosperma* F.Muell., [MEL2089466], *Acacia cibaria* F.Muell., [= *Acacia brachystachya* Benth.] [MEL724434] and *Tribulus forrestii* F.Muell., [MEL79403]). Some collections are labelled with Jones as the collector in November 1877 and may have been collected after Mueller returned to Perth on 16 November. Jones has collections dated as 1878 and 1879 at Irwin and Greenough Rivers and then at Gascoyne River and the vicinity of Shark Bay 1880–1885 (AVH 2022). There are no collections known outside these years. The name of the 'native constable' is not known or any details about his involvement.

---

[20] F. Mueller to Louise Wehl, 29 Sept. 1884. Home *et al.* (2023+).

[21] Ferdinand Mueller's last will and testament, 17 June 1894. Home *et al.* (2023+).

[22] *The Australasian* (Melbourne). Arrived. 6 Oct. 1877, p. 14.

[23] *The Evening Journal* (Adelaide). Latest news. 6 Oct. 1877, p. 2.

[24] *The Evening Journal* (Adelaide). Latest news. 8 Oct. 1877, p. 2.

[25] *The Sydney Morning Herald*. Adelaide. 9 Oct. 1877, p. 5.

[26] *The Western Australian Times*, Arrival of the colonial mail. 12 Oct. 1877, p. 2.

[27] *The Herald* (Fremantle). Governor Robinson. 13 Oct. 1877, p. 3.

[28] *The Herald* (Fremantle). Mail news. 20 Oct.1877, p. 3.

[29] *The Herald* (Fremantle). Mail news. 20 Oct.1877, p. 3.

[30] *The Inquirer and Commercial News* (Perth). St. George's Vestry. 17 Oct. 1877, p. 3.

[31] *The Herald* (Fremantle). Shipping report. 20 Oct. 1877, p. 2.

[32] *The Western Australian Times*. Abstract of news. 30 Oct. 1877, p. 2.

From Champion Bay, Mueller travelled to the Murchison River and onto Shark Bay and the Peron Peninsula. Mueller wrote: 'I rode from the Murchison River across to Shark's Bay: no habitation for 100 miles, and no water for 70 miles. A large number of the Murchison River plants were traced by me to Peron's Peninsula, Shark's Bay' (Mueller 1878a: 151). With regard to the vegetation, Mueller wrote: 'As I anticipated I did not observe much novelty, but I was able to trace numerous species over a much wider geographic area, than that previously known, and I had also many opportunities of improving the diagnosis of numerous species'.[34] Mueller (1883: 4) wrote that he could only spend two days at Shark Bay because of 'prior arrangements for early forest services in the South'. Mueller also made collections from the Irwin and Greenough rivers, but whether he visited those locations prior to, or after he returned from Shark Bay cannot be determined on the available data.

During his travels to Shark Bay, Mueller received support from Andrew Jameson Ogilvie (1855–1906) for whom he named *Lasiopetalum ogilvieanum* F.Muell. (Table 1). In the protologue for the name, Mueller (1881: 108) wrote: 'I mentioned this evidently rare species to my friend A.J. Ogilvie, who kindly supported my journey from the place of discovery of this plant to Shark Bay'. Nothing is recorded about their meeting or what kind of support was provided by Ogilvie. Ogilvie was a prominent pastoralist in the Murchison River/Shark Bay region.[35]

Based on a collection made by Mueller in the Murchison River to Shark Bay area, he named *Lhotskya harvestiana* F.Muell. [= *Calytrix harvestiana* (F.Muell.) Craven] to acknowledge the support he received from Lieut.-Colonel Edward Douglas Harvest, writing that he (incorrectly as 'William' Harvest by Mueller) 'has lately most kindly assisted my phytological journeys' (Table 1). Harvest was acting governor of Western Australia, 7 September 1877 to 12 November 1877, during the interval between the departure of Sir W.C.F. Robinson and the arrival of Sir Harry St. George Ord.[36]

Available data (AVH 2022; MELISR) indicate that Mueller collected about 160 specimens during the Champion Bay to Shark Bay excursion, of which 16 represented new taxa (Table 1).

Mueller departed Champion Bay on about 15 November to arrive in Fremantle on 17 November.[37] In Perth, he was the guest of John Forrest.[38] On 20 November, Mueller and Forrest travelled to Northam by horses provided by the police department.[39] It was reported in a newspaper that: '…we had a flying visit in Northam from Baron Von Mueller, the celebrated botanist, who was accompanied by Mr. John Forrest. The Baron, who arrived in the evening and left in good time on the following day, was able to collect some seeds of our trees which he was anxious to obtain'.[40] Mueller and Forrest departed Northam on 21 November, travelling 'beyond York' together.[41] Similar to Mueller's travels to Shark Bay, official assistance was provided in the form of horses and guides and with the order from Superintendent of Police Matthew Smith to Sub-inspector William Piesse that at Northam 'should he [Mueller] require a horse to ride or a constable to guide him anywhere let him have them'.[42] On 23 November, Mueller and Forrest travelled to the 'Fluted Gum Forest a few miles from Jurinceme'.[43] The Fluted Gum refers to *Eucalyptus salubris* F.Muell., 'of the West-Australian colonists, so called on account of the broad longitudinal often twisted impressions or wide blunt longitudinal ridges of the stem' (Mueller 1879–1884, decade 9, 8th plate), but the place name, partly illegible, has not been identified. Whilst Forrest returned to Perth soon after, Mueller remained in the area but was in Perth by at least 26 November according to dated correspondence (Mueller 1878a). One new species, *Eucalyptus salmonophloia* F.Muell., was described by Mueller (1878b) based on a collection from Upper Swan River with the epithet given 'in allusion to the smooth grey and somewhat purplish bark of an oily lustre' (Mueller 1879–1884, decade 9: 7th plate) (Table 1).

---

[33] F. Mueller to Oliver Jones, 1 Jan. 1880. Home *et al.* (2023+).

[34] F. Mueller to James Hector, 1 Jan. 1878. Home *et al.* (2023+).

[35] *The Geraldton Express*. Local and general. 12 Oct. 1906, p. 2.

[36] *The Western Australian Times* (Perth). Succession of governors in West Australia. 6 June 1879, p. 7.

[37] *The Herald* (Fremantle). Shipping report. 24 Nov. 1877, p. 2.

[38] *The Inquirer and Commercial News* (Perth). Telegraphic news. 21 Nov. 1877, p. 3.

On about 30 November, Mueller commenced his excursions in the south. His intention was to 'travel on a new line to Geography Bay [sic], and thence to the hilly country about Point Entrecasteaux [sic] and Point Nuyts, where the back ranges have never yet been traversed by any naturalist' (Mueller 1878a: 151), and 'to examine generally the country lying between Cape Leuwin [sic] and King George's Sound'[44] before returning to Melbourne.

After leaving Perth, Mueller travelled via Serpentine River (1 Dec.), Pinjarra (3 Dec.), Harvey River (5 Dec.) and Collie River to arrive in Bunbury on about 6–7 December (AVH 2022). At Pinjarra, Mueller engaged with Captain Theodore Fawcett (1832–1898), commanding captain of the Pinjarra Mounted volunteers. The volunteers were a corps founded by Fawcett and active from 1862 until 1882 (Wieck 1962). A collection of *Xanthorrhoea* [MEL2216303, 3 Dec. 1877] has a label in Mueller's hand that reads: 'Brought by Capt Fawcett's aboriginal, stem thick, (arboresc) Peduncle 2 foot. Spike short. Supposed to be distinct from *X. preissii*, with which it seems to grow intermixed'. It is not known if Mueller had other interactions with Fawcett or the indigenous person who supplied the specimen.

Mueller had another intention when he visited Bunbury. This was to examine a block of land that he had purchased. The block had originally been granted by Western Australian Governor Robinson to surveyor Ernest Giles for his contribution to exploration in Western Australia and Giles subsequently old it to Mueller.[45] It was a 2000 acre (809 hectare) block in the Bunbury/Geographe Bay area. The exact boundaries of the land have not been established although Mueller later referred to it as taking

---

[39] Matthew Skinner Smith, Superintendent of Police, Perth, to Captain William Roper Piesse, Northam. Police Department, Chief Office, Perth, Nov. 20th 1877, draft transcript provided by Mueller correspondence project.

[40] *The Western Australian Times* (Perth). Country news. 7 Dec. 1877, p. 3.

[41] F. Mueller to Roger Goldsworthy, 27 Dec. 1877. Home *et al.* (2023+).

[42] Matthew Smith (Perth) to William Piesse (Northam), Police Department, Chief Office, Perth, Nov. 20th 1877, draft transcript provided by Mueller correspondence project.

[43] From William Piesse to Matthew Smith, 23 Nov. 1877. Cons 129, no. 25/409, State Records Office of Western Australia, draft transcript provided by Mueller correspondence project.

[44] *The Inquirer and Commercial News* (Perth). Monthly summary for the mails. 26 Dec. 1877, p. 3.

[45] Ernest Giles to Harry Ord, 18 Mar. 1878. Home *et al.* (2023+).

Table 1. New taxa described from specimens collected by Ferdinand Mueller in Western Australia during October–December 1877.

Acacia adnata F.Muell., *Chem. & Drugg. Australas. Suppl.* 5(51): 26 (1882).

Type citation: Near the Irwin River; F.v.M.

Mueller specimens: holo: K000806105 [K catalogue has it as isotype]; iso: MEL2073980, NSW216929; status not designated: PERTH708747.

Typification: Cowan and Lewington (*Fl. Australia* 11B: 62 (2001)).

Acacia amblyophylla F.Muell., *S. Sci. Rec*. 2(7): 149 (1882).

Type citation: Near Shark-Bay; F.v.M.

Mueller specimens: holo: MEL615148; iso: NSW, PERTH143006; photo of holotype: PERTH739928.

Typification: Maslin (*Fl. Australia* 11A: 287 (2001)).

Brachyscome latisquamea F.Muell., *Fragm*. 11: 16 (1878) [= ***Pembertonia latisquamea*** (F.Muell.) P.S.Short).

Type citation: Ad sinum marinum Shark-Bay in locis tempore pluviali humidis; F.M. Prope Champion-Bay, C.Gray.

Mueller specimens: lecto: MEL239618 p.p.; isolecto: MEL239618 p.p.

Typification: Short (*J. Adelaide Bot. Gard*. 28: 169 (2014)).

Comesperma rhadinocarpum F.Muell., *Fragm*. 11: 1 (1878).

Type citation: In virgultis ad fluvios Greenough's, Arrowsmith's et Irwin's River; F.M.

Mueller specimen: status not designated: MEL98608.

Typification: No recent treatment.

Note: van Steenis (*Acta Bot. Neerl*. 17: 383 (1968)) proposed the new combination *Bredemeyera rhadinocarpa* (F.Muell.) Chodat ex Steenis, but did not indicate typification. This action has not been accepted in Australia.

Darwinia forrestii F.Muell., *Fragm*. 11: 9 (1878) **[=** ***Chamelaucium forrestii*** (F.Muell.) N.G.Marchant].

Type citation: In rupibus graniticis ad summitatem montis Burrobunup prope flumen Gordon's River; F.M.

Mueller specimens: lecto: MEL2290893; isolecto: CGE, GH00068981, MEL2290894, MEL726509, MEL726510, PERTH06796427.

Typification: Marchant (*Nuytsia* 30: 323 (2019)).

Deyeuxia abscondita T.D.Macfarl., *Nuytsia* 31: 179, Figs 1, 2 (2020).

Type citation: Preston's River [Preston River], Western Australia, 8 December 1877, F.Mueller s.n. (holo: MEL 72092); Blackwood & Preston River, Western Australia, 8 December 1877, F.Mueller s.n. (iso: PERTH ex MEL 2127721A).

Mueller specimens: holo: MEL72092; iso: MEL2127721.

Typification: Macfarlane (*Nuytsia* 31:179 (2020)).

Note: At time of writing, MEL2127721 had not yet been transferred to PERTH (pers. comm, T. Macfarlane).

Eremaea violacea F.Muell., *Fragm*. 11: 10 (1878).

Type citation: In plagis arenosis ad fluvios Irwin's, Arrowsmith's et Greenough's River; F.M.

Mueller specimens: holo: MEL526437; iso: CBG, K000793698, MEL526438, PERTH.

Typification: Hnatiuk (*Nuytsia* 9(2): 162 (1993)).

Eucalyptus salmonophloia F.Muell., *Fragm*. 11: 11 (1878).

Type citation: In silvis ad flumen cygnorum ejus ostium versus, F.M.; abhine usque in viciniam oasis Victoria-Spring passim occurrens; E.Giles.

Mueller specimens: syn: MEL1517645, MEL1517646, MEL1517647, MEL567376, MEL567377, MEL567379, MEL567380, MEL567381, MEL569054, NSW346141.

Typification: Chippendale (*Fl. Australia* 19: 262 (1988)).

Note: Maiden (*Crit. Revis. Eucalyptus* 2(7): 217 (1912)) corrected the location of Mueller's collection to the head of the Swan River, rather than the mouth of the river as stated by Mueller.

Eucalyptus todtiana F.Muell., *S. Sci. Rec*. 2: 171 (1882).

Type citation: Near the Greenough and Arrowsmith River on sandy ridges, F.v.M.; near the Moore-River, J.Forrest.

Mueller specimens: syn: K (not found on K catalogue), MEL567390, MEL568930, MEL1517660, NSW354141.

Typification: Chippendale (*Fl. Australia* 19: 131 (1988).

Gastrolobium forrestii Ewart, *J. Proc. R. Soc. N.S.W.* 42: 188 (1908) [= ***Gastrolobium cuneatum*** Henfr.].

Type citation: Blackwood River, W.A., Sir John Forrest; W.Aust. 1889; Gordon River in forest land, 1877.

Mueller specimen: status not designated: MEL247648.

Typification: Chandler *et al.* (*Aust. Syst. Bot.* 15(5): 636 (2002)).

Note: Chandler *et al.* cited only Forrest specimens as types, not the Mueller specimen.

Halgania argyrophylla Diels, *Bot. Jahrb. Syst.* 35(2–3): 491 (1904).

Type citation: in distr. Irwin pr. Irwin River et Greenough Riv. (F.v.Müller in hb. Melbourn.!), pr. Northampton in arenosis aridis fruticulosis flor. m. Nov. (D. 5642).

Mueller specimen: lecto: MEL80049.

Typification: Holstein and Gottschling (*Aust. Syst. Bot.* 31(2): 115 (2018)).

Hibbertia cunninghamii var. *debilis* F.Muell. *Fragm*. 11: 93, *adnot*. (1880)

Type citation: detexi ad cataractas fluvii Serpentine-River.

Mueller specimens: status not designated: MEL666578, MEL666579.

Typification: Name of uncertain application (APNI, https://biodiversity.org.au/nsl/services/search/names.)

Hibbertia rhadinopoda F.Muell., *Fragm.* 11: 91 (1880) [= ***Hibbertia diamesogenos*** (Steud.) J.R.Wheeler].

Type citation: In pratis fertilioribus ad flumen Harvey's River; F.M.

Mueller specimens: holo: MEL1010265, MEL1010266; status not designated: NSW436256, K000700348,

Typification: Wheeler (*Nuytsia* 15(2): 327 (2004)).

Hibbertia teretifolia var. *bisulcata* F.Muell., *Fragm*. 11: 95 (1880) [= ***Hibbertia rupicola*** (S.Moore) C.A.Gardner].

Type citation: a Champion-Bay (C.Gray), flumine Irwinii (F.M.) ad montes Stirlingii et promontorium Cape Arid (Maxwell).

Mueller specimen: syn: MEL666842.

Typification: Wheeler (*Nuytsia* 15(2): 296 (2004)).

Hybanthus debilissimus F.Muell., *Fragm*. 11: 4 (1878) [= ***Pigea debilissima*** (F.Muell.) P.I. Forster].

Type citation: In silvis Karri-forests secus flumen Shannon; F.M.

Mueller specimens: iso: AD, MEL26772, MEL26774, MEL26775; status not designated: K000327662, MEL26773.

Typification: Bennett (*Nuytsia* 1(3): 235 (1972)).

Lasiopetalum ogilvieanum F.Muell., *Fragm*. 11: 107 (1881).

Type citation: In locis sabulosis inter fluvios Greenough et Irwin River; F.M.

Mueller specimens: lecto: MEL52370; iso: K000686566, MEL52369.

Typification: Shepherd and Wilkins (*Nuytsia* 32:140 (2021)).

Lhotskya harvestiana F.Muell., *Fragm*. 11: 8 (1878) [= ***Calytrix harvestiana*** (F.Muell.) Craven].

Type citation: Inter flumen Murchison's River et sinum marinum Shark-Bay; F.M.

Mueller specimens: holo: MEL545045; iso, fragm: PERTH01065246.

Typification: Craven (*Brunonia* 10(1): 59 (1987)).

Mesomelaena stygia var. *deflexa* Kük., *Repert. Spec. Nov. Regni Veg.* 48: 53 (1940) [= ***Mesomelaena stygia* subsp. *deflexa*** (Kük.) K.L.Wilson]

Type citation: West-Australien: Zwischen den Arrowsmith – und Irwin – Rivers XI.1877 (F.Mueller! in herb. Phytol. Mus. Melbourne.)

Mueller specimens: holo: B 10 0296663; status not designated: K000960095, NSW722253.

Typification: Wilson (*Telopea* 2(2): 192 (1981)).

Ptilotus stirlingii var. *pumilus* Benl, *Muelleria* 1(2): 108 (1959) [= ***Ptilotus stirlingii*** (Lindl.) F.Muell. subsp. ***stirlingii***].

Type citation: Type from Sharks Bay, Western Australia (Holotype of variety in MEL – F.Mueller, Oct., 1877).

Mueller specimens: holo: MEL2219748; status not designated: MEL2219742, MEL2219745.

Typification: Davis and Butcher (*Nuytsia* 20: 268 (2010)).

Roebuckia cheilocarpa var. *integra* P.S.Short, *J. Adelaide Bot. Gard.* 28: 175 (2014) [= ***Roebuckia cheilocarpa*** (F.Muell.) P.S. Short var. ***cheilocarpa***]

Type citation: Western Australia. Between Shark Bay & Murchison River, F.Mueller (holotype: MEL 692820).

Mueller specimens: holo: MEL692820; status not designated: MEL692558, MEL692818, MEL692819, MEL692822.

Typification: Short (*J. Adelaide Bot. Gard.* 28: 175 (2014)).

Statice salicorniacea F.Muell., *Fragm*. 11: 7 (1878) [= ***Muellerolimon salicorniaceum*** (F.Muell.) Lincz.]

Type citation: In locis salinis ad margines oceani usque, secus paeninsulam Peronis et portum Freycinetti sinus Shark-Bay; F.M.

Mueller specimens: holo: MEL44400; iso: K0007866676.

Typification: No recent treatment, but see Linczevski (*Botaniceskij Zurnal SSSR*: 676 (1982)) for transfer to *Muellerolimon*.

Note: The combination *Goniolimon salicorniaceum* (F.Muell.) Christenh. & Byng, proposed by Christenhusz *et al*. (*Global Flora* 4: 144 (2018)) has not been accepted in Australia.

Tetragonia diptera F.Muell., *Fragm*. 11: 8 (1878).

Type citation: Ad sinum marinum Shark-Bay; F.M.

Mueller specimens: syn: MEL99772, MEL99773; status not designated: K000768359).

Typification: Prescott (*Fl. Australia* 4: 40 (1984)).

Note: Prescott designated a specimen at MEL as an isotype.

Trachymene xerophila E.Pritz., *Bot. Jahrb. Syst*. 35(2–3): 453 (1904) [= ***Platysace xerophila*** (E.Pritz.) L.A.S.Johnson].

Type citation: loco non indicato (Drummond 189 in hb. Berol.!), in distr. Avon septentrionali pr. Watheroo in arenoso-glareosis flor. m. Nov., Dec., Jan. (E.Pritzel Pl. Austr. occ. 988, D. 2123), in distr. Irwin pr. Irwin Riv. (F.v.Müller in hb. Berol.!), pr. Dogara in fruticetis apertis arenosis flor. m. Dec. (D. 5726).

Mueller specimens: syn: MEL2254700, MEL2290564; status not designated: MEL2254699.

Typification: Johnson (*Contrib. N.S.W. Natl Herb*. 3: 101 (1962)).

Xerotes ordii F.Muell., *Fragm*. 11: 23 (1878) [= ***Lomandra ordii*** (F.Muell.) Schltr.]

Type citation: In vallibus silvaticis ad flumen Shannon, ejus ostium versus; Muir, F.M.

Mueller specimens: syn: MEL20555, MEL20556, MEL20557, MEL20558, MEL20560, MEL20561, WUP0002284; isosyn K (not found on K catalogue); status not designated: PERTH1069012 (photo of the K sheet).

Typification: Lee and Macfarlane (*Fl. Australia* 46: 118 (1986)).

Xyris indivisa N.A.Wakef., *Western Australian Naturalist* 4: 80, fig. 7 (1954).

Type citation: Holotype: Karri Forest, swampy banks of the Shannon River, F.Mueller, 12/12/1877 (MEL, duplicate at PERTH).

Mueller specimens: holo: MEL73442; iso: PERTH01086367.

Typification: Conn and Doust (*Aust. Syst. Bot.* 10: 243 (1997)).

in Ferguson Creek (an upper tributary of Preston River).[46] Giles sold the block to Mueller for £800 in June 1877.[47] After examining the block, Mueller expressed disappointment with its potential and conveyed that it required considerable development to make it of any financial benefit to him. It was reported by a Bunbury correspondent that 'Baron Von Mueller is, after all, not likely to become a landowner in this district, much to our regret and loss. The 2000 acres selected did not meet with his approval, while the rent offered by a settler whose land adjoins - £2 per annum - settled the matter as an eligible investment. After visiting the land in question and spending two or three days with us the

---

[46] F. Mueller to Malcolm Fraser, 7 July 1878. Home *et al.* (2023+).

[47] Ernest Giles to F. Mueller, 2 June 1877. Home *et al.* (2023+).

Baron proceeded overland to Albany'.[48] Mueller subsequently attempted to recoup his £800 outlay and explained his situation in a letter to Forrest, writing that he 'could not accept the land selected & wished to sell the right of selection' and that 'the land in question can doubtless be made into a valuable estate by spending £10 an acre on clearing the timber, fencing, building, and by ploughing the small share of its areable [sic] land'.[49] Both Giles and Forrest interceded on Mueller's behalf in attempting to resolve the matter,[50] although how the issue was finally resolved is not clear. Mueller soon after sought another block of land near Perth,[51] but that was rejected by the Western Australian government.[52] Mueller had, in November 1877, applied to Governor Ord for Western Australian naturalisation on the basis that he intended to invest in land in the colony.[53] However, this was rejected as Mueller did not intend to reside in the colony.[54]

Travelling south-eastward, Mueller passed Preston River (7–8 Dec.) and the Blackwood River/Warren River area (9–10 Dec.). It is not known whom he travelled with at this time, but from 12–18 December he was in the company of George Maxwell and Thomas Muir, and possibly his brothers Andrew Muir and John Reid Muir (Mueller 1878c). It is probable that he met with these men earlier, but the available evidence indicates that they travelled together on the dates noted above. In regard to the Muirs, Mueller had a previous association in the early 1870s with John Reid Muir who collected specimens for him. AVH (2022) lists about 400 collections by J.R.Muir. Mueller (1873) named *Lepyrodia muirii* F.Muell. for him as the collector. As well as collecting with Mueller in 1877, Thomas Muir in subsequent years sent specimens to Mueller. The degree of involvement of Andrew Muir is not known and there is no evidence that he collected specimens for Mueller.

It is most probable that Maxwell, the Muirs and Mueller travelled together in the vicinity of Shannon River (12 Dec.), Warren River (12 Dec.), Burrobunup (14 Dec.), Gordon River (14–16 Dec.) and Lake Muir (14 Dec.) (AVH 2022). Mueller (1879: 5) commented on the distribution of the ornamental *Eucalyptus ficifolia* F.Muell. [= *Corymbia ficifolia* (F.Muell.) K.D.Hill & L.A.S.Johnson] noting that 'this species is very limited; it extends, according to Messrs. Muir and Maxwell, from the western side of Irwin's Inlet to the mouth of the Shannon'. Mueller could not have personally seen the species in the wild as the route taken did not go far enough south. His admiration for the ornamental qualities of the species was undoubtedly based on cultivated specimens. He wrote that 'hardly anything more gorgeous can be imagined than the forest of *E. ficifolia* about the month of February, when the brilliant trusses of flowers diffuse a rich red over the dark-green foliage of the whole landscape'. The species does not form 'forests' *per se* and the currently known distribution of the species takes in that described by Mueller as well as outlier populations to the east and north of Albany.

Mueller (1878c: 146) noted that 'the best plant of this latter part of the journey is a stately *Xerotes* from the valleys of the Lower Shannon'. He described it as *Xerotes ordii* F.Muell. [= *Lomandra ordii*

---

[48] *The Herald* (Fremantle). Country news. 29 Dec. 1877, p. 3.

[49] F. Mueller to John Forrest, 14 Feb. 1878. Home *et al.* (2023+).

[50] John Forrest to Colonial Secretary. 2 Mar. 1878. Colonial Secretary's Office, SDUR/M8/900J, State Archives, Battye Library, Perth; Ernest Giles to Harry Ord, 18 Mar. 1878. Home *et al.* (2023+); John Forrest to Malcolm Fraser, 4 Apr. 1878. Home *et al.* (2023+).

[51] F. Mueller to Harry Ord, 8 Nov. 1878. Home *et al.* (2023+); F. Mueller to Harry Ord, 26 Nov. 1878. Home *et al.* (2023+).

[52] Alexander Forrest to F. Mueller, 26 Oct. 1878. Home *et al.* (2023+); Roger Goldsworthy to F. Mueller, 26 Nov. 1878. Home *et al.* (2023+).

[53] F. Mueller to Harry Ord, 20 Nov. 1877. Home *et al.* (2023+).

[54] Roger Goldsworthy to F. Mueller, 26 Nov. 1877. Home *et al.* (2023+).

(F.Muell.) Schltr.] in recognition of Governor Harry Ord (1819–1885) for 'having evinced a great interest in my researches here'. Ord was governor of Western Australia 1877–1880. Mueller noted that he 'was directed to this showy plant by Mr. Muir, who had previously noticed it in the few localities to which it is confined' (Table 1). Mueller (1878b: 9) also named a new species for John Forrest from 'Burrobunup' (possibly Granite Peak or Mt Roe: for discussion on those place names see Hearn *et al*. (2006) and Marchant (2019)), *Darwinia forrestii* F.Muell. [= *Chamelaucium forrestii* (F.Muell.) N.G.Marchant], for 'whose kind assistance I enjoyed in my recent journey' (Table 1).

Mueller continued travelling onto Albany during the following week. En route or after arriving in Albany, he visited Walpole, Chorkerup (collections dated 18–24 Dec.), Kamballup (18 Dec.), Torbay (20–22 Dec.), Hay River, Wilsons Inlet (20–24 Dec.) and King River (25–26 Dec.). By about 27 December he was preparing to return to Melbourne (Mueller 1878c). Mueller departed Albany on 29 December on R.M.S.S. *Assam* and arrived in Melbourne on 4 January, 1878.[55] Eight new taxa were described on collections made by Mueller in south-west of Western Australia between Perth to Albany, December 1877 and are presented in Table 1.

Mueller's contribution to the Western Australian flora after 1877

Mueller worked on numerous publications that dealt with aspects of the Western Australian flora in the years up to his death in 1896. With a decrease in the potential to describe taxonomic novelties, Mueller set about to complete a number of illustrated monographs and other publications that summarised what was then known about the Australian flora (Hewson 1999). The inclusion of Western Australian plants was an essential element in establishing an assessment, as thorough as possible, of the flora of the entire continent.

***Report on the forest resources of Western Australia*, 1879**

In his *Report on the forest resources of Western Australia,* Mueller (1879) provided detailed descriptions and superb illustrations of 17 species of *Eucalyptus* (some now in *Corymbia*), as well as brief notes on species of *Agonis*, *Acacia*, *Banksia*, *Callitris* (as *Frenela*), *Casuarina*, *Melaleuca* and *Santalum*. The illustrations were prepared by Robert Austen (1851–1879), who, at the age of 28, died soon after publication of the work.[56] Mueller, in correspondence to Joseph Hooker, wrote: 'Sad to record, my poor draftsman Austin [sic], after a long and severe illness (nephritis) has died and this needs now the training of another artist for the purpose'.[57] Austen's illustrations were prepared as lithographs by the renowned John Nugent Fitch (1840–1927) and printed in London by Vincent Brooks, Day & Sons, then among the most renowned printing companies in England. Printing was facilitated by Joseph Hooker from Kew Gardens,[58] and publication costs, about £300, were borne by the Western Australian government.[59]

Three plates of analytical illustrations were prepared by Ludwig Rummel. During the 1870s, Rummel was employed as an analytical chemist and microscopist at Mueller's phytochemical laboratory at the Melbourne Botanic Gardens (Rae & Maroske 2020). Of interest is the public 'disagreement' that developed between Rummel and Mueller in 1881 when Rummel accused Mueller of failing to acknowledge his contributions as a chemist and deprecating his role in the translation of Wittstein's (1878) *Chemistry of plants*.[60] Mueller wrote in the preface to the work: 'I feel great pleasure in acknowledging the co-operation of Mr. L. Rummel, who for many years conducted many phyto-chemic and technic operations in my laboratory, in aiding me throughout in the work of translation, and also in its revision, while it was passing through the press'. In an indignant retort, Rummel claimed that 'whatever the Baron has published during the last 10 years, under his own or our joint names, in regard to original researches and discoveries in the provinces of phyto-chemistry and microscopy, has been my own work, unaided, except of course by legitimate reading. The translation also into the English language of Dr Wittstein's *Chemistry of Plants* has been done by me, the Baron's share of the work being restricted to some trifling alterations, and to the nomenclature of the plants'.[61] Rummel unsuccessfully claimed compensation from the Victorian government when he was dismissed in 1881: he was deemed an employee of Mueller and not necessarily to be a public servant employed by the government.[62]

---

[55] *The Argus* (Melbourne). The R.M.S.S. *Assam*. 5 Jan. 1878, p. 7.

[56] *The Argus* (Melbourne). Family notices. 23 May 1879, p. 1.

[57] F. Mueller to Joseph Hooker, 6 July 1879. Home *et al.* (2023+).

[58] F. Mueller to Joseph Hooker, 16 Aug. 1879. (Home *et al.* 2023+).

[59] F. Mueller to John Forrest, 11 Sept. 1879. (Home *et al.* 2023+).

***Eucalyptographia. A descriptive atlas of the eucalypts of Australia and the adjoining islands*, 1879–1884**

Mueller noted in 1879 in the introduction to the first decade (published sections of ten illustrations each) of *Eucalyptographia* that it was a continuation of the treatment of the eucalypts that he presented in *Report on the forest resources of Western Australia* but that the work presented was only a preliminary account as 'there is no limit to a work of this kind, particularly when it is remembered, that the eucalypts form the principal timber-vegetation nearly all over the wide Australian continent'. In a summarising comment when the work was completed in 1884, Mueller wrote that 'specific demarcation moreover can in most cases not yet be drawn with completeness and accuracy for want either of sufficient museum-material, or of opportunities to study their characteristics further in culture or in free nature. Moreover the eucalypts, which remain yet to be dealt with, are mostly restricted to widely distant and as yet hardly accessible localities'. Although Mueller was aware that other species were yet to be described and that new discoveries had been made about the existing species, he was not able to publish the additional work that he had hoped.

Of the 118 species treated in *Eucalyptographia*, 39 were from Western Australia, of which 30 were considered endemic (Mueller 1879–1884). Not all species that were treated were illustrated. The work was published in ten decades thus amounting to 100 species being illustrated. Of these, 34 were Western Australian species. Two of the Illustrations were the work of Robert Austen (*Eucalyptus diversicolor* F.Muell. and *E. erythrocorys* F.Muell.) and six plates of analytical illustrations were by Ludwig Rummel. These included details of bark, transverse sections of leaves, cell structure, anthers, cuticle arrangement and wood structure. The majority of the illustrations were prepared by Emil Hermann Todt (1809–1900). Todt was born in Berlin and migrated to South Australia in 1849 and then the Victorian goldfields in 1851 (Lance 2006). He was a trained sculptor most active in Victoria, remembered for his work 'The gold diggers' that was first exhibited in 1854,[63] and now in the collection of the National Gallery of Victoria.[64] His connection to Mueller dates from at least 1862, when he 'skilfully executed the task of modelling Victorian fruits entrusted to him by Dr Mueller' for the Victorian Court at the London International Exhibition.[65] It is not known how Todt was engaged by Mueller as an illustrator for *Eucalyptographia*. One review reported on the illustrations in that 'they are all faithfully depicted by Mr. Emil Todt, to whom the Baron accords a deserved meed of praise for the ardor he brought to bear on the furtherance of the present publication'.[66] Todt was seventy-five years of age when the work was published and it was to be his last significant artistic endeavour (Lance 2006). Mueller acknowledged him by naming *Eucalyptus todtiana* F.Muell. (Table 1). In the protologue Mueller (1882a: 171) wrote: 'Named in honor of Mr. Emil Todt, through whose artistic talent numerous species became illustrated for the "Atlas of Eucalypts"'. In treating *E. todtiana* in *Eucalyptographia*, Mueller (1879–1884, decade 9, 11th plate) added that Todt 'became devoted only to illustrating plants at a venerable age, when most of those, engaged in such pursuits, have ceased to work professionally. Therefore all the more praise is due to this gentleman for the youthful ardour, which he still brought to bear on the extensive furtherance of the present publication'. Unlike *Report on the forest resources of Western Australia*, which was printed in London, the lithographs in *Eucalyptographia* were prepared in Melbourne by Charles Troedel & Co. Ltd.

---

[60] *The Argus* (Melbourne). Baron von Mueller and Mr. L. Rummel. 27 May 1881, p. 7; *The Argus* (Melbourne). The Baron von Mueller and Mr. L. Rummel. 30 May 1881, p. 6.

[61] *The Argus* (Melbourne). Baron von Mueller and Mr. L. Rummel. 27 May 1881, p. 7.

[62] *The Argus* (Melbourne). Parliament. 20 May 1881, p. 5.

[63] *The Argus* (Melbourne). The exhibition. 20 Oct. 1854, p. 5.

[64] National Gallery of Victoria. The gold diggers. https://www.ngv.vic.gov.au/explore/collection/work/3628/.

Description and illustrations of the Myoporinous plants of Australia, 1886

The next illustrated monograph by Mueller dealt with the genera *Eremophila* and *Myoporum*, placed by him in the Myoporinae [= Scrophulariaceae]. In the preface to the work, Mueller (1886c: Preface) described them as consisting of 'frutescent and arborescent plants entirely, and which on this account forms at many places a prominent part in the Australian flora … extensively distributed over all parts of the Australian continent … attaining their highest development in the hottest and most arid regions of this portion of the globe'. Some 74 species were illustrated, the total thus far accounted for Australia at that time. Of these, 48 species occurred in Western Australia and of which 23 were considered endemic. The illustrations were prepared by Robert Graff, Mueller (1886c: Preface) writing that the illustrations 'do credit to his artistic skill, and this all the more, as these lithographic drawings are his first effort in botanic direction'. This publication lacked any text, Mueller noting in the preface that: 'The descriptive portion of this publication will be given somewhat later'. Mueller proposed a treatment of the Australian Myoporinae for Alphonse de Candolle's *Monographiae phanerogamarum* with expected publication of the Latin version in 1887 and an English version, to include the plates, in 1888.[67] However, this did not eventuate and Mueller's work on the Myoporinae consists of the lithographic plates with brief captions and no significant text. The lithographs were prepared by C. Troedel & Co., Melbourne. Very little verifiable biographical information is presently available on the artist Robert Graff. There are newspaper notices that refer to a Robert Graff in Victoria, some certainly apply to Robert Graff the artist associated with Mueller's illustrated monographs from 1886 until 1892,[68] whilst other notices apply to a farmer from Hansonville, Greta District, more than likelyanother Robert Graff.[69]

---

[65] *The Argus* (Melbourne). Victorian fruits at the exhibition. 17 July 1862, p. 7.

[66] *The Leader* (Melbourne). Eucalyptographia. 31 May 1884, p. 14.

[67] F. Mueller to Alphonse de Candolle, 15 May 1886. (Home et al. 2023+); F. Mueller to Alphonse de Candolle, 25 Dec. 1886. (Home *et al*. 2023+).

[68] The Argus (Melbourne). Family notices. 16 Apr. 1886, p. 1; The Age (Melbourne). Births. 27 Dec. 1887, p. 1; The Herald (Melbourne). Collision with buggy. 22 Jan. 1913, p. 3.

[69] The Ovens and Murray Advertiser (Beechworth). Oxley Shire Council. 13 May 1893, p. 5; The Leader (Melbourne). Family notices. 21 Nov. 1914, p. 60; The Wangaratta Chronicle. Death at Melbourne. 25 Nov. 1914, p. 2; The Argus (Melbourne). Advertising. 15 Dec. 1914, p. 1.

Iconography of Australian species of Acacia and cognate genera, 1887–1888

Perhaps the most ambitious of Mueller's illustrated works was his *Iconography of Australian species of Acacia and cognate genera* (Mueller 1887–1888). The work comprised 13 decades, 1–8 in 1887 and 9–13 in 1888, with a total of 130 illustrations. These included *Acacia*, 118 spp., *Adenanthera*, 1 sp., *Albizzia*, 1 sp., *Archidendron,* 4 spp., *Archidendropsis,* 2 spp., *Cathormium*,1 sp., *Erythrophloeum*, 1 sp., *Neptunia*, 1 sp. and *Pararchidendron*, 1 sp. Of these, 24 species were from Western Australia, of which 17 were endemic. As a continuation of Mueller's plan to produce illustrated monographs, he wrote of the acacias in the introduction that 'it was deemed best, to devote the next volume to those native species of *Acacia*, of which hitherto no drawings had appeared anywhere … so that a work like the present one seemed specially called for'. As with *Description and illustrations of the Myoporinous plants of Australia*, the illustrations were prepared by Robert Graff, the lithographs by Charles Troedel & Co. and it was printed in Melbourne. Mueller (1887–1888: Introduction) wrote that Graff's work on the acacias demonstrated 'patient perseverance as well as artistic accomplishment'. The Western Australian species *Acacia graffiana* F.Muell. [=*A. hemiteles* Benth.], based on a Drummond collection, was named for him, with Mueller (1887: 118) writing in the protologue that Graff was an 'accomplished and zealous artist, who recently finished the lithographic illustrations of the "myoporinous plants," and who has since drawn and engraved many plates for the Iconography of Australian Acacias and allied genera'. Mueller also noted the assistance of George Luehmann, Mueller's herbarium assistant, he being responsible for specimen selection on the basis that they were complete with each having a full complement of leaves, flowers and fruit, 'a principle adhered to also in all the former illustrated publications of the author' Mueller (1887–1888: Introduction). Unless Mueller had access to a complete specimen for an individual species, he did not include it in the illustrated publications.

The work was well received with reviews appearing in newspapers and magazines. The most thorough were presented in *The Sydney Mail and New South Wales Advertiser* with each completed decade being reviewed, and on completion of the thirteenth decade, summarised as: 'Baron Mueller has now completed the first volume of his great work on the *Acacia* and Cognate Genera of Australia, and has dedicated it in complimentary terms to Sir Henry B. Loch, Governor of Victoria. This volume contains 130 figures of plants hitherto but imperfectly described "a large systematic assemblage of plants," the author remarks, "particularly important for horticulture and technology"'.[70] Although unsigned, it is known through correspondence that the reviews were prepared by Rev. William Woolls.[71] A review in the *Gardeners' Chronicle* stated: 'Australian Acacias. Baron von Mueller has completed with the thirteenth decade his series of lithographic illustrations of the species of this large, intricate, and interesting group. The work will not only be valuable to botanists for the care and fullness with which the structural details have been treated, but also to horticulturists in enabling them to identify their plants; while to the colonist the importance of correct nomenclature and ready means of discriminating species possessed of such useful properties as yielding timber, gum, tannin etc., can hardly be over-estimated' (Anon. 1889).

---

[70] *The Sydney Mail and New South Wales Advertiser*. Australian species of *Acacia*. 29 Dec. 1888, p. 1331.

[71] *The Sydney Mail and New South Wales Advertiser*. Lithograms of the genus *Acacia.* 26 Nov. 1887; *The Sydney Mail and New South Wales Advertiser*. Work on the *Acacia* and cognate genera. 4 Feb. 1888; *The Sydney Mail and New South Wales Advertiser*. Australian *Acacia* and cognate genera. 25 Aug. 1888, p. 380; *The Sydney Mail and New South Wales Advertiser*. Australian *Acacia* and cognate genera. 1 Sept. 1888, p. 436; *The Sydney Mail and New South Wales* Advertiser. Australian acacias. 17 Nov. 1888, p. 1023; William Woolls to F. Mueller, 24 Aug. 1888, draft transcript provided by Mueller correspondence project.

Iconography of Australian Salsolaceous plants, 1889–1891

The illustrated monograph of Australia's saltbushes [Salsolaceae Menge = Chenopodiaccae Vent], was, according to Mueller (1889–1891), predicated on 'not only a multitude of endemic forms of high phytologic interest, but also a considerable number of prominent utilitarian value. The "Saltbushes" constitute in many wide tracts of our island-continent the prevailing vegetation, and on this again depends then locally to a large extent the sustenance of herds and flocks'. The work included 90 lithographs, which were published in nine decades, 1–2 in 1889, 3–6 in 1890 and 7–9 in 1891. Both the illustrations and lithographs were prepared by Robert Graff, the artist who prepared Mueller's two previous illustrated monographs. The lithographs were printed by the Government Printing Office, Melbourne. Of the 90 species illustrated, 44 were from Western Australia, of which nine were endemic. One newspaper report noted that 'Baron Mueller is of opinion that several species now known only in Western Australia might be cultivated advantageously in Eastern Australia. In a matter so important the Agricultural Society would render great service to the pastoral interests by ascertaining from experiment whether such is the case'.[72] This report is in the style of William Woolls, but there is no known correspondence to verify his authorship.

Iconography of Candolleaceous plants, 1892

The first decade of this family [Candolleaceae F.Muell. = Stylidiaceae R.Br.] was the last illustrated monograph to be published by Mueller. Mueller wrote that the first decade would possibly be the only one published as he had no staff or financial means to continue with the project.[73] The illustrations and lithographs were once again prepared by Robert Graff, and printed by the Government Printing Office, Melbourne (Mueller 1892). Ten species of *Candollea* Labill. [= *Stylidium* Sw. ex Willd.] were illustrated. Of these, six were from Western Australia and all endemic.

Other publications by Mueller that dealt with the Western Australian flora

Second systematic census of Australian plants, with chronologic, literary and geographic annotations, 1889

Mueller's nomenclatural 'choices' and systematic relationships of all known Australian plant species were laid out in his *Second systematic census of Australian plants*. The work provided a rearrangement of the species included in Bentham's *Flora Australiensis*, as well as new species described since completion of that work in 1878. It was also an update of Mueller's first census of 1882 (Mueller 1882b). In the *Second systematic census*, Mueller (1889) stated that of the 8839 Australian species he listed, 3560 were recorded for Western Australia, which was 40.3% of the Australian flora. A calculation based on his numbers indicates that of the Western Australian species recognised by Mueller, 73% were considered endemic at that time. Data from the Western Australian Herbarium (2023) suggest that the number of native species as of 2022 was 14959 (including unpublished phrase names), about four times the number proposed by Mueller in 1889.

---

[72] *The Sydney Mail and New South Wales Advertiser*. Salsolaceous plants. 30 Apr. 1892, p. 974.

[73] F. Mueller to Thomas Wilson, 8 Apr. 1893. Home *et al.* (2023+); F. Mueller to Walter Gill, 9 Aug. 1895. Home *et al.* (2023+).

***The vegetation of Western Australia* and *List of extra-tropic West Australian plants* (*Vasculares*), 1896**

These combined accounts were among Mueller's last publications prior to his death in 1896. *The vegetation of Western Australia*, written for the Western Australian Year Book 1894–95, was a preliminary synopsis of the flora of the colony. It was written in a style that gave flourishes of affectionate admiration, sometimes poetically, for plant genera and species and their formation into one of the world's most unique floras. One newspaper reported on the informality of the work as 'Baron von Mueller gossips pleasantly on the vegetation of the colony'.[74] On a sombre note, Mueller (1896a: 200) wrote, knowing that he would never personally visit Western Australia again in his lifetime: 'In parting sorrowfully and reluctantly from this charming flora, with the elaborating of which the writer throughout more than forty years has become prominently identified, and which to his extreme regret he can hardly hope ever to see again'. In the accompanying *List of extra-tropic West Australian plants (Vasculares)*, Mueller (1896b) provided a systematic arrangement of those species occurring south of the Tropic of Capricorn. This included about 100 families, 580 genera and 3700 species, which was a moderate increase in the number of Western Australian species that Mueller presented in 1889 in the *Second systematic census of Australian plants*. Bickford (1897: 279) indicated that Mueller 'till within almost the last few hours preceding his death, was engaged compiling for 1897 a complete census of Western Australian phanerogamic and cryptogamic plants; this consequently was not concluded'. However, an updated census was prepared by Morrison (1902) in which he stated that 'in compiling the present list, acknowledgement must be made of the assistance rendered by Mr. J.G. Luehmann, Government Botanist at Melbourne, who has supplied some alterations determined on by the late Baron before his death. These will be found under the genera *Aotus* and *Dillwynia*, *Waitzia*, *Perotis*, and *Anthistiria*, and may be taken as indicative of the Baron's latest views thereon'. This can be accepted as Mueller's final contribution to the flora of Western Australia.

Acknowledgements

Barry and Jenn Muir are thanked for information on the Muir family history in Western Australia. Arthur Lucas is thanked for constructive comments and suggestions for additional citations and information about Mueller's activities. Philip Bertling provided copies of rare documents held in the Royal Botanic Gardens Victoria Library. Juliet Wege and Terry Macfarlane (PERTH) provided information on the collections of Thomas Muir. Two reviewers are sincerely thanked for their suggestions and corrections.

References

Anon. (1889). Australian Acacias. The Gardeners' Chronicle: a weekly illustrated journal of horticulture and allied subjects, 3rd series, no. 106, vol. 5, January 5, p. 18.

Archer, B. & Maroske, S. (1996). Sarah Theresa Brooks - plant collector for Ferdinand Mueller. *Victorian Naturalist* 113: 188–194.

AVH (2022). *Australasian Virtual Herbarium*. https://avh.chah.org.au, accessed Nov. 2022–Mar. 2023.

Beard, J.S. (1980). A new phytogeographic map of Western Australia. *Western Australian Herbarium Research Notes* 3: 37–58.

Bentham, G. (1878). Concluding preface. *Flora Australiensis.* Vol. 7. pp. v–viii. (L. Reeve & Co.: London.)

Bickford, E.J. (1897). The vegetation of Western Australia. *In*: Fraser, M.A. (ed.) *Western Australian Year-Book for 1895–96.* pp. 279–284. (Government Printer: Perth.)

Churchill, D.M., Muir, T.B. & Sinkora, D.M. (1978). The published works of Ferdinand J.H. Mueller (1825-1896). *Muelleria* 4: 1–120.

Cohn, H.M. (1996). Botanical researches in Intertropical Australia: Ferdinand Mueller and the North Australian Exploring Expedition. *Victorian Naturalist* 113: 163–168.

---

[74] *The Geraldton Advertiser*. Our year-book. 31 Aug. 1896, p. 2.

Cohn, H.M. & Maroske, S. (1996). Relief from duties of minor importance: the removal of Baron von Mueller from the directorship of the Melbourne Botanic Garden. *Victorian Historical Journal* 67(1): 103–127.

Diels, L. (1906). *Die Pflanzenwelt von West-Australien südlich des Wendekreises. Mit einer Einleitung über die Pflanzenwelt Gesamt-Australiens in Grundzügen. Ergebnisse einer im Auftrag der Humboldt-Stiftung der Kgl. Preussischen Akademie der Wissenschaften, 1900–1902 unternommenen Reise*. (W. Engelmann: Leipzig.)

Diels, L. (1981) (translated by D.J. Carr). Extra-tropical Western Australia. *In*: Carr, D.J. & Carr, S.G.M. (eds) *People and plants in Australia*. pp. 47–78. (Academic Press: Sydney.)

Diels, L. (2007) (translated by B.J. Grieve, B.B. Lamont & E.O. Hellmuth). The plant life of Western Australia south of the tropic with an introductory part dealing with the salient features of the vegetation of the whole of Australia, the results of an expedition undertaken during 1901–1902 under the auspices of the Humboldt Foundation, Royal Prussian Academy of Science. *Conservation Science Western Australia* 6(2): 1–373.

Dowe, J.L. (2020). The Australian paintings of Marianne North, 1880–1881: landscapes 'doomed shortly to disappear'. *Cunninghamia* 20: 001-033, doi: 10.7751/cunninghamia.2020.20.001.

Dowe, J.L., May, T.W., Maroske, S. & Smith, L.T. (2020). The Wehl family of South Australia and their botanical connections with "Dear Uncle" Baron Ferdinand von Mueller. *Swainsona* 34: 1–79.

Dowe, J.L. & Schweizer, E. (2022). *Livistona victoriae* and the North Australian Exploring Expedition 1855–1856. *Palms* 66(2): 90–102.

George, A.S. (2009). *Australian botanist's companion*. (Four Gables Press: Kardinya, W.A.)

Gregory, A.C. (1857). North-Australian Expedition; letter from A.C. Gregory, Esq., commander of the expedition. *Hooker's Journal of Botany and Kew Garden Miscellany* 9: 201–209, 230–243.

Gregory, A.C. (1858). Journal of the North Australian Expedition, under the command of Augustus C. Gregory, Esq. (Gold Medallist R.G.S.); with report by Mr. Elsey on the health of the party. *Journal of the Royal Geographical Society* 28: 1–137.

Hay, A. (2021). *Gum: the story of eucalypts and their champions*. (NewSouth Publishing: Sydney.)

Hearn, R.W, Meissner, R., Brown, A.P., Macfarlane, T.D. & Annels, T.R. (2006). *Declared rare and poorly known flora in the Warren Region. Western Australian Wildlife Management Program No. 40*. (Published jointly by Australian Government Department of Environment and Heritage, Canberra and Western Australian Department of Conservation and Land Management, WA.)

Henderson, W.G. (2011). George Maxwell: Bushman and naturalist. *Early Days: Journal of the Royal Western Australian Historical Society* 13(5): 626–648.

Hewson, H. (1999). *Australia: 300 years of botanical illustration*. (CSIRO Publishing: Collingwood.)

Home, R.W., Darragh, T.A., Lucas, A.M., Maroske, S., Sinkora, D.M., Voigt, J.H. & Wells, M. (eds) (2023+). *Correspondence of Ferdinand von Mueller*, Royal Botanic Gardens Victoria. https://vmcp.rbg.vic.gov.au, accessed Nov. 2022–Mar. 2023.

Lance, T. (2006). A life revealed: Emil Todt, a German sculptor in nineteenth-century Melbourne. *Art Bulletin of Victoria* 46: 28–35.

Marchant, N.G. (2019). Circumscription of *Chamelaucium* (Myrtaceae: Chamelaucieae), with validation of six species names and two new combinations. *Nuytsia* 30: 317–334.

Maroske, S. (2014). 'A taste for botanic science': Ferdinand Mueller's female collectors and the history of Australian botany. *Muelleria* 32: 72–91.

Maroske, S. & Vaughan, A. (2014). Ferdinand Mueller's female plant collectors: a biographical register. *Muelleria* 32: 92–172.

Morrison, A. (1902). Flora. The vegetation of Western Australia. *In*: Fraser, M.A.C. (ed.) *Western Australian Year-Book for 1900–01*. pp. 298–341. (Government Printer: Perth.)

Mueller, F. (1856). North Australian botany. *Hooker's Journal of Botany and Kew Garden Miscellany* 8: 321–331.

Mueller, F. (1857a). Nova genera et species aliquat rariores in plagis Australiae intratropicis nuperrime detecta. *Hooker's Journal of Botany and Kew Garden Miscellany* 9: 14–24.

Mueller, F. (1857b). Notes made during the recent expedition across the northern portion of Australia, under the command of Mr. Surveyor Gregory. *Hooker's Journal of Botany and Kew Garden Miscellany* 9: 165–173, 193–199, 225–230.

Mueller, F. (1857c). On some genera of Australian plants, discovered during the progress of the North Australian Exploring Expedition. *Hooker's Journal of Botany and Kew Garden Miscellany* 9: 302–310.

Mueller, F. (1867). *Australian vegetation, indigenous or introduced, considered especially in its bearings on the occupation of the territory, and with a view of unfolding its resources*. (Blundell & Co.: Melbourne.)

Mueller, F. (1873). Restiaceae. *Fragmenta Phytographiae Australiae* 8: 64–101.

Mueller, F. (1878a). Foreign correspondence. Swan River, Perth, Western Australia. *The Gardeners' Chronicle: a weekly illustrated journal of horticulture and allied subjects,* new series, no. 214, vol. 9, February 3, p. 151.

Mueller, F. (1878b). Myrtaceae. *Fragmenta Phytographiae Australiae* 11: 8–15.

Mueller, F. (1878c). Foreign correspondence. King George's Sound. *The Gardeners' Chronicle: a weekly illustrated journal* *of horticulture and allied subjects*, new series, no. 240, vol. 10, August 3, p. 146.

Mueller, F. (1879). *Report on the forest resources of Western Australia*. (L. Reeve & Co.: London.)

Mueller, F. (1879–1884). *Eucalyptographia. A descriptive atlas of the eucalypts of Australia and the adjoining islands*. (John Ferres: Melbourne and Trubner & Co.: London.)

Mueller, F. (1880). The late Mr. Maxwell. *The Gardeners' Chronicle: a weekly illustrated journal of horticulture and allied subjects*, new series, no. 327, vol. 13, April 3, p. 433.

Mueller, F. (1881). A catalogue of plants collected during Mr. Alexander Forrest's geographical exploration of north-west Australia in 1879. *Journal and Proceedings of the Royal Society of New South Wales* 14: 81–95.

Mueller, F. (1882a). Definitions of some new Australian plants. *Southern Science Record* 2: 171.

Mueller, F. (1882b). *Systematic census of Australian plants, with chronologic, literary and geographic annotations*. (M'Carron, Bird & Co.: Melbourne.)

Mueller, F. (1883). *The plants indigenous around Sharks Bay and its vicinity, chiefly from collections of the Honorable John Forrest C.M.G., F.L.S., F.R.G.S., surveyor general of Western Australia*. (Richard Pether: Perth.)

Mueller, F. (1886a). The flora of Australasia. *In*: Garran, A. (ed.) *Picturesque Atlas of Australia*. Vol. 3, pp. 715–727. (Picturesque Atlas of Australia Publishing Co., Ltd.: Sydney.)

Mueller, F. (1886b). *Plants collected in Capricornic Western Australia, by H.S. King, Esq., and recorded by Baron von Mueller, K.C.M.G, M. & Ph.d., F.R.S.* (Mason, Firth & M'Cutcheon: Melbourne).

Mueller, F. (1886c). *Description and illustrations of the Myoporinous plants of Australia*. (John Ferres: Melbourne.)

Mueller, F. (1887). Notes on Australian plants. *The Chemist and Druggist of Australasia* 2(5): 118.

Mueller, F. (1887–1888). *Iconography of Australian species of Acacia and cognate genera*. (John Ferres: Melbourne.)

Mueller, F. (1889). *Second systematic census of Australian plants, with chronologic, literary and geographic annotations*. (McCarron, Bird & Co.: Melbourne.)

Mueller, F. (1889–1891). *Iconography of Australian Salsolaceous plants*. (Robert S. Brain: Melbourne.)

Mueller, F. (1892). *Iconography of Candolleaceous plants*. (Robert S. Brain: Melbourne.)

Mueller, F. (1896a). The vegetation of Western Australia. *In*: Fraser, M.A.C. (ed.) *Western Australian Year-Book for 1894–95*. pp. 195–200. (Government Printer: Perth.)

Mueller, F. (1896b). List of extra-tropic West Australian plants (Vasculares). *In*: Fraser, M.A.C. (ed) *Western Australian Year-Book for 1894–95*. pp. 201–231. (Government Printer: Perth.)

North, M. (1892). *Recollections of a happy life being the autobiography of Marianne North edited by her sister Mrs. John Addington Symonds*. 1st Edition, 2 vols. (MacMillan & Co.: London.)

Rae, I.D. & Maroske, S. (2020). Ferdinand von Mueller's phytochemical laboratory. *Historical Records of Australian Science* 31: 26–38.

Short, P.S. (1997). Some notes concerning J.D. Batt. *Australian Systematic Botany Newsletter* 90: 16–20.

Trove (2022). *Newspapers and gazettes*. https://trove.nla.gov.au/newspapers, accessed Nov.-Dec. 2022.

Western Australian Herbarium (2023). *Florabase-the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au.

Wieck, G.F. (1962). *The Volunteer Movement in Western Australia 1861–1903*. (Paterson Brokensha: Perth.)

Wittstein, G.C. (1878). *The organic constituents of plants and vegetable substances and their chemical analysis. Authorised translation from the German original, enlarged with numerous additions by Baron Ferd. von Mueller*. (M'Carron, Bird & Co.: Melbourne.)

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01058

Nuytsia 34: 179–186
Published online 20 July 2023

Echinostelium australiense (Myxomycetes: Echinosteliaceae), a new species of slime mould described from Western Australia

Karina J. Knight[1], Steven L. Stephenson[2] and Yuri K. Novozhilov[3]

[1]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2]University of Arkansas, Department of Biological Sciences,
Fayetteville, Arkansas 72701, USA
[3]V.L. Komarov Botanical Institute of the Russian Academy of Sciences,
Prof. Popov Street 2, 197376 St Petersburg, Russia
[1]Corresponding author, email: Karina.Knight62@gmail.com

Abstract

Knight, K.J., Stephenson, S.L. & Novozhilov, Y.K. *Echinostelium australiense* (Myxomycetes: Echinosteliaceae), a new species of slime mould described from Western Australia. *Nuytsia* 34: 179–186 (2023). A new and unusual species of *Echinostelium* de Bary appearing on samples of bark collected in Western Australia and placed in moist chamber cultures is described and illustrated. This new species is clearly distinct from all other species of *Echinostelium* as it differs in a number of morphological and colour characters. The dark colouration of the sporotheca, stalk and spores with distinct patches of closely arranged warts arranged in a loosely circular pattern, and a large bi-coloured petaloid collar are unusual for the genus.

Introduction

Echinostelium is a genus of myxomycetes (slime moulds) in which the inconspicuous sporocarps generally occur on the bark of living trees, with occasional occurrences on vines or various types of dead plant material (Keller & Brooks 1976; Whitney 1980; Haskins & Clark 2016) and very rarely on the weathered dung of herbivorous animals (Novozhilov & Schnittler 2008). Due to a short-lived life cycle strategy and the diminutive size of sporocarps, mostly less than 0.5 mm in height with the exception of *E. novozhilovii* A.Vlasenko, which can reach a height of 2.5 mm (Vlasenko *et al.* 2018), new records and new species are usually observed from material recovered using the moist chamber technique and examination of substrate samples under a dissecting microscope.

An unusual new myxomycete was first discovered by the late English myxomycologist David W. Mitchell. Specimens were harvested from moist chamber cultures in late 2002 (pers. correspondence Margaret H. Brims) on bark samples of *Dryandra sessilis* (Knight) Domin, currently *Banksia sessilis* (Knight) A.R.Mast & K.R.Thiele, collected from Stoneville, *c*. 30 km east of Perth, Western Australia (*Mitchell* 6749). Mitchell regarded this as a potential new species of *Echinostelium* and provided a short description, diagnosis, and image in a paper published shortly after its discovery (McHugh *et al.* 2003). The following year, one of the authors of the aforementioned paper (the late Margaret H. Brims), harvested the collection of the specimen listed below in a moist chamber culture prepared

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

with bark samples from *Eucalyptus todtiana* F.Muell. from Hi Vallee farm near Badgingarra, *c.* 250 km north-north-west of Perth, Western Australia (*Brims* 685). At the time, the significance of the find was overlooked, and the specimen was deposited in the Western Australian Herbarium. Subsequent research has shown that these unusual specimens represent a new taxon, described here, thus confirming Mitchell's original idea.

Echinostelium is a relatively small genus with only 16 species (Lado 2005–2023) but with a worldwide distribution (GBIF Secretariat 2001–2023). Some species (e.g. *E. colliculosum* K.D.Whitney & H.W.Keller), are common in arid regions (Novozhilov *et al*. 2006; Novozhilov & Schnittler 2008) but it seems are rare or absent in humid tropics (Schnittler & Stephenson 2000; Novozhilov *et al*. 2017). The 11 species recorded for Australia are *E. apitectum* K.D.Whitney, *E. arboreum* H.W.Keller & T.E.Brooks, *E. bisporum* (L.S.Olive & Stoian.) K.D.Whitney & L.S.Olive, *E. brooksii* K.D.Whitney, *E. coelocephalum* T.E.Brooks & H.W.Keller, *E. colliculosum*, *E. corynophorum* K.D.Whitney, *E. elachiston* Alexop., *E. fragile* Nann.-Bremek., *E. minutum* de Bary and *E. paucifilum* K.D.Whitney; of these, *E. colliculosum* is the only species not known from Western Australia. Stephenson (2021) states 6 species are not known from Australia (*E. cribrarioides* Alexop., *E. ladoi* Pando, *E. lunatum* L.S.Olive & Stoian., *E. microsporum* A.Vlasenko, *E. novozhilovii* A.Vlasenko and *E. paucifilum*), however *E. paucifilum* was recently recorded from Western Australia (GBIF Secretariat 2001–2023). The description of the new species *E. australiense* K.J.Knight, S.L.Stephenson & Novozh. brings the Australian species to 12 (nine in Western Australia) and the world total to 17 species.

Methods

The moist chamber culture technique used for the substrate samples collected by the first author took into consideration the morphology and hygrophobic nature of the bark of *Eucalyptus todtiana*. The bark of *E. todtiana* is longitudinally fibrous, and large samples were required to maintain their integrity in the moist chamber. The samples were thick, up to 1.5 cm, and relatively long, up to 10 cm. Substrate samples were submerged in distilled water for about 10 seconds to help break the surface tension on the upper surface, and left to soak for 24 or 36 hrs. The substrate samples soaked for 36 hrs were more productive than those soaked for 24 hrs; however, it is unknown whether the longer soak period caused the difference. The pH of the soak water was recorded with an EcoTestr pH2 handheld meter, and after excess soak water was removed the substrate samples were placed in lidded plastic containers, the base lined with paper towel and maintained at room temperature in diffuse light following ambient night/day conditions. Microscopic examination was carried out on dried specimens rehydrated and mounted in Hoyer's solution. Scanning electron micrographs by Novozhilov were obtained with a JSM-6390 LA scanning electron microscope (SEM) at 10–15 kV using cryo-dried specimens and those by Dillon with a Neoscope JCM-5000 SEM at 10 kV. All mounts were on copper stubs via double-sided sticky film and sputter-coated with gold.

Taxonomy

Echinostelium australiense K.J.Knight, S.L.Stephenson & Novozh., *sp. nov.* (MB 838442).

Type: Hi Vallee Farm, 5 km east of Brand Highway on Tootbardi Road, *c.* 250 km north-north-west of Perth, Western Australia, 22 August 2020, *K.J. Knight* MC 284 [from a moist chamber culture of the bark of living *Eucalyptus todtiana*, 7 September 2020] (*holo*: PERTH 09260307, *iso*: MA).

Echinostelium sp. (DWM 6749), D.W. Mitchell in McHugh *et al.* (2003).

Sporocarps scattered to gregarious, stalked, 60–180 µm high. *Hypothallus* bulbous and/or minutely disc-like, often inconspicuous, fuscous-black or reddish-black. *Stalk* 100–180 µm long, curved or inclined, frequently nodding, cylindrical, tapering up from an expanded base 20–35 µm diam. to a narrow apex 3–4 µm diam., bicoloured, lower part (1/4–3/4) dull black, upper part more or less shiny, pale yellow or colourless, stalk walls colourless, grading to a translucent grey-brown for about 10 µm just below the apex, stuffed with dark, granular refuse giving a roughened appearance on the outer surface, refuse variably less dense distally, sometimes almost completely filling the stalk. *Sporotheca* essentially globose with a somewhat flat base, 32–55 µm diam., dark grey to black when freshly mature, fuscous black when dry, robust, clinging to the spore-like body, or when dislodged, often dropping as a cohesive unit. *Peridium* membranous, early fugacious except for a large persistent collar attached to the lower half of the spore-like body, widely petaloid, minutely striate, divided into two distinct portions, the inner basal portion flat or widely saucer shaped, well defined, small, about 10 µm diam., almost stellate with distinct striations, brown or violaceous-brown, the outer portion hyaline, faintly violaceous, striations less distinct and interrupted, appearing as lines of warts, edge of peridium minutely irregularly stellate or roughened, somewhat thickened and recurved. *Columella* absent. *Spore-like body* present, usually single, rarely twinned, globose or more usually subglobose with a flat base, 13–20 µm wide, 12–17 µm high, often with an attached spore, but more usually sandwiched between two or more spores, the spores adhering to the peridial collar, colour and ornamentation same as the spores. *Capillitium* absent. *Spores* by transmitted light grey-brown or grey-lilac, mostly globose, sometimes subglobose or ovoid or appearing very slightly angular, (12–)13–18(–19) µm diam., the spore wall of uniform thickness, verruculose, with conspicuous, minute, variably sized and unevenly distributed warts which are often very scattered, with rather discreet, approximately circular darker patching formed by closely arranged warts, sometimes forming clusters of 2–5 warts, when viewed by SEM the warts of the dark patching are arranged in small arcs, lines, groups or joined to form short ridges, sometimes warts are also arranged on the edge of the patch in a circular pattern, warts overall are taller than wide and flat- or round-topped, smooth or minutely ridged. *Plasmodium* not observed. (Figures 1, 2)

Diagnostic characters. This species is readily distinguished from all other species of *Echinostelium* by the following combination of characters: a fuscous black sporotheca with the spores joined together in a cohesive unit; distinctly bicoloured stalk, with the lower part black and the apical region by transmitted light grey-brown; peridial collar widely petaloid, divided into two distinctly coloured areas, brown in lower half and faintly violaceous and hyaline in upper part, the edge somewhat thickened and recurved; spores and spore-like body relatively dark, grey-brown or grey-lilac by transmitted light, the ornamentation distinct, with patches of closely arranged warts arranged in a loosely circular pattern.

Other specimens examined. WESTERN AUSTRALIA: Hi Vallee Farm, Badgingarra, 2 Apr. 2004, *M.H. Brims* 685 (PERTH 07213840); Hi Vallee Farm, 5 km E of Brand Hwy on Tootbardi Road, *c*. 250 km NNW of Perth, 9 Feb. 2020, *K.J. Knight* MC 281 (PERTH 09260277), *K.J. Knight* MC 282 (PERTH 09260285), *K.J. Knight* MC 283 (PERTH 09260293); Hi Vallee Farm, 5 km E of Brand Hwy on Tootbardi Road, *c*. 250 km NNW of Perth, 22 Aug. 2020, *K.J. Knight* MC 285 (PERTH 09260315), *K.J. Knight* MC 286 (PERTH 09260854), *K.J. Knight* MC 287 (PERTH 09362185); Stoneville, date unknown, *D.W. Mitchell* 6749 (K).

Ecology, distribution, and habitat. Associated with the acidic bark of living *Eucalyptus todtiana* (pH of soak water 3.4 – *K.J. Knight* MC 281, MC 282, MC 283, and pH 4.0 – *K.J. Knight* MC 284, MC 285, MC 286, MC 287) and *Banksia sessilis*. The most productive moist chambers were those prepared with the substrate samples collected at the end of a winter-wet period and may have been more favourable for this species versus the substrate samples collected after a hot dry summer. The

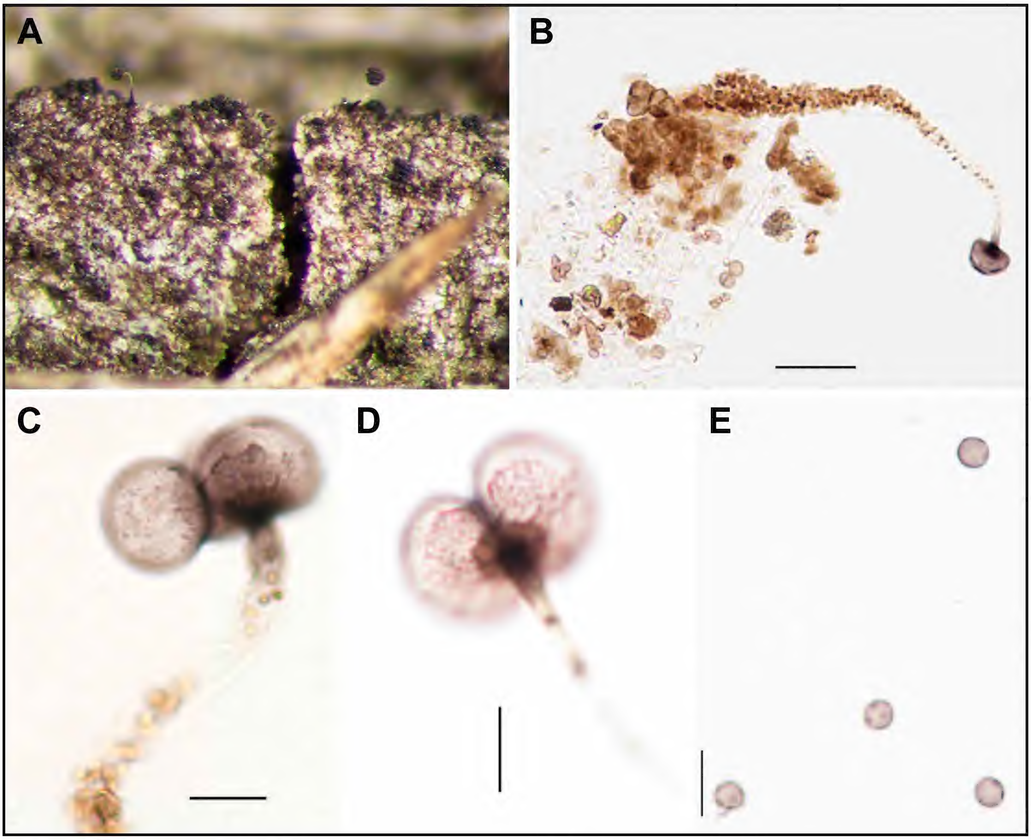

Figure 1. *Echinostelium australiense*. A – two sporocarps *in situ* showing the habit with nodding or inclined stalks, black lower stalk, and black sporotheca; B – sporocarp by transmitted light showing the granular stalk with a coloured grey-brown apex just below the subglobose spore-like body; C – sporocarp by transmitted light showing spore-like body draped with a large bi-coloured, minutely striate peridial collar along with a spore adhering to the spore-like body and peridial collar; D – sporocarp by transmitted light showing a twinned spore-like body with a large bicoloured, minutely striate and petaloid peridial collar; E – spores by transmitted light showing the rather discreet, approximately circular areas of darker patching. Images from *K.J. Knight* MC 281 (B); MC 284 (A, D); MC 285 (C, E). Photographs by J.M. Huisman & K.J. Knight. Scale bars: 100 µm (A); 30 µm (B, E); 10 µm (C, D).

two localities the species is recorded from are disjunct in Western Australia, occurring in semi-arid and warm areas in the Geraldton Sandplains and Jarrah Forest bioregions (Department of Environment 2013). The *K.J. Knight* and *M.H. Brims* collections are from proteaceous scrub-heath in an open eucalypt woodland, while the *D.W. Mitchell* collection is from a region characterised by a shrubland associated with a Jarrah-Marri forest.

The *D.W. Mitchell* collection (DWM 6749) indicates that the substrate was the bark of *Banksia sessilis* (McHugh *et al.* 2003); at the time the bark was collected there was some doubt about this. From personal correspondence between Mitchell and Brims in early 2003, the description of the plant from which the substrate was collected was described as ‘needle-like, grey-green leaves, bark bare of epiphytes, flaked in strips, leaves looked quite xerophytic’. Brims questioned the taxon name as the leaf description did not match *Banksia sessilis.* However, Mitchell further confirmed the plant’s identity with the comment ‘the specimen did have small holly-like leaves with tiny irregularly distributed black dots on the pale blue-green leaves’. The bark of living plants of *Banksia* typically decorticate

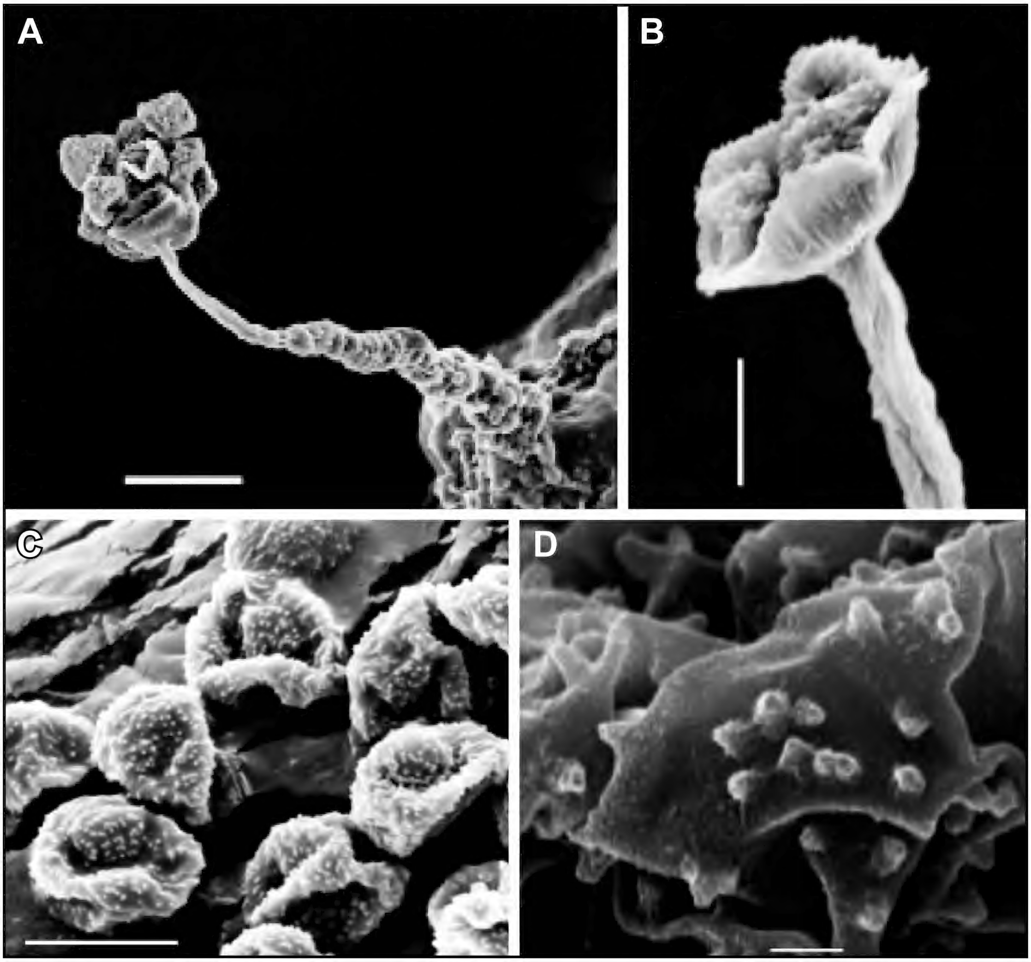

Figure 2. *Echinostelium australiense* as viewed with scanning electron microscopy. A – sporocarp showing the tapering stalk, rough below and a large peridial collar; B – large minutely striate petaloid collar showing the minutely widely stellate or roughened, somewhat thickened and recurved edge; C – collapsed spores showing sparsely warted ornamentation between the rather discreet, approximately circular darker patching with the warts arranged in clusters, lines or joined; D – spore ornamentation formed by rounded or flat topped warts and when clustered with minute ridges between the warts. Images from *K.J. Knight* MC 284 (B); MC 285 (A, C); MC 286 (D). Photographs by Steve Dillon (A-C) and Yuri Novozhilov (D). Scale bars: 20 µm (A); 5 µm (B); 10 µm (C); 0.5 µm (D).

only in very mature individuals and then in small rectangular chips that adhere to the tree trunk (pers. obs. KJK and pers. comm. A.S. George) vs 'flaked in strips' as described by Mitchell. After viewing the Mitchell collection, it is clear the substrate is not as indicated *Banksia sessilis* but is likely to be a species of *Eucalyptus* with fibrous bark. It should also be noted that the geocode provided for the Mitchell collection in McHugh *et al.* (2003) is incorrect since it places the collection *c.* 53 km west-south-west of Stoneville (in the ocean just west of Fremantle).

Conservation status. Myxomycetes in Western Australia are poorly known and until recently were rarely collected. Although *E. australiense* is known from just two disjunct localities approximately 250 km apart, it is not considered to be under conservation threat since its occurrence is likely to be more common and widespread.

Etymology. The epithet is from the Latin *australiense*, the name Mitchell coined (as '*australis'*) in correspondence with Brims in early 2003 (15/1/2003) and refers to its discovery in Australia.

Vernacular name. Black Echinostelium.

Affinities. *Echinostelium australiense* is clearly distinct and could not be confused with other species in the genus since it differs in a number of readily apparent morphological and colour characters. The dark colouration of the sporotheca, stalk, and spores in *E. australiense* is unusual for the genus, which more typically has a pale sporotheca, a hyaline to pale brown stalk of uniform colour, and pale or hyaline spores (Haskins & Clark 2016). It is easily distinguished from the other species with spore-like bodies (*E. apitectum*, *E. coelocephalum*, *E. colliculosum*, *E. ladoi*, and *E. novozhilovii*) by the diagnostic characters listed above, which do not occur in combination within this grouping. The spores of *E. elachiston* have a similar distribution of warts as *E. australiense*, described by Pando and Oltra (2000) as warted, sometimes coarsely, the warts irregularly distributed or more characteristically grouped in clusters giving the impression of forming pads. *Echinostelium australiense* is readily distinguished from *E. elachiston* by the presence of a spore-like body (vs a rudimentary capillitium), the larger sporotheca 32–55 µm (vs 30–40 µm), dark coloured sporotheca and stalk (vs pale colouring) and size of spores 12–19 µm diam. (vs 6–8 µm).

The stalks of the genus *Echinostelium* are typically cylindrical tubes with a small, solid, translucent, colourless apical region (Haskins & Clark 2016). The apical region in *E. australiense* is typical except for the grey-brown colouring for the uppermost 10 µm. This type of stalk and colouring is characteristic of both its sister genus *Barbeyella* Meyl., where the stalk is black at the apex (Kowalski & Hinchee 1971), and the genus *Clastoderma* A.Blytt, where it may be brown as in *C. debaryanum* A.Blytt, reddish-brown as in *C. microcarpum* (Meyl.) Kowalski and *C. pachypus* Nann.-Bremek. (Haskins & Clark 2016) or black as in *C. confusum* K.J.Knight & Lado (Knight & Lado 2020). *Echinostelium australiense* is readily distinguished from the genus *Barbeyella* by the presence of a spore-like body (vs a cylindric columella dividing at the middle of the sporotheca into rudimentary capillitium) and an early fugacious peridium with remnant collar (vs persistent lobes); and distinguished from the genus *Clastoderma* by the presence of a spore-like body (vs columella present or absent and capillitium always present).

The peridium of *Echinostelium* is typically fugacious and hyaline, remaining only as a small basal collar attached to the stalk, although it may be somewhat persistent in a few species before it is reduced to a collar or breaks into peridial fragments that remain attached to the capillitial tips as in *E. arboreum* (Haskins & Clark 2016). The peridium of *E. australiense* is typical for the genus only in its fugacious nature; otherwise, it is uniquely petaloid, variously ornamented with striations and with two distinct portions, an inner section conspicuously coloured brown and the outer portion faintly violaceous.

The black sporotheca and relatively dark, grey-brown or grey-lilac spores with conspicuous warts as observed under transmitted light in *E. australiense* are unique for the genus. Typically, the spores of *Echinostelium* by transmitted light are hyaline, with pale yellowish or lilac hues and the ornamentation described as smooth or minutely roughened, although by SEM some ornamentation is usually present in the smooth state (Haskins & Clark 2016). An exception to this is the recently described *E. microsporum*, where although the colour is typically pale and hyaline, the spores are described as ornamented with distinct large warts (Vlasenko *et al.* 2019). In the recent phylogeny of the class Myxomycetes (Leontyev *et al.* 2019), the presence of dark (melanised) spores separates the pale-spored genus *Echinostelium* from its sister genus *Barbeyella*. The presence of dark spores in *E. australiense* suggests that the melanisation of the spores is possibly less diagnostic than previously accepted and the generic limits of *Echinostelium* may eventually be broadened. Doing so would result in the primary criterion separating the genus *Barbeyella* from *Echinostelium* being the presence of a tough persistent peridium (vs fugacious, or as membranous remnants as in *E. arboreum*).

Echinostelium australiense retains its spores on the collar at maturity, or when the spores are dislodged, they tend to drop as a cohesive unit. This contrasts with most other species of *Echinostelium*, also without a capillitium, in which the spores readily disperse and are usually lacking on herbarium specimens (Whitney 1980). The rather discreet, approximately circular darker patching of the spore formed by closely arranged warts may play a role in this, the warts interlocking to some extent (Figure 2D). The areas of patching on the spores of *E. australiense* as observed by transmitted light do not appear conspicuously thickened, but may be somewhat flattened, giving the spore a slightly angular outline (Figure 1E). The rather discreet, approximately circular area of dark patching appears more rigid than the surrounding spore wall as it retains an almost flat, plate-like circular shape when the remaining spore wall is desiccated and collapsed inwards (Figure 2C). The presence of the lower spores adhering to the large peridial collar may also enhance the cohesiveness of the sporotheca (Figures 1C, 2C). It is interesting to note the likely presence of a second species of dark-spored *Echinostelium*. According to the third author, one of his colleagues (Konstantin Fefelov, from Ekaterinburg, Russia) recovered a single collection of what was clearly a species of *Echinostelium* with a dark sporotheca and dark spores from a moist chamber culture. However, it can be readily distinguished from *E. australiense* by its hyaline stalk throughout (vs bicoloured with a very dark base) and seemingly smooth spores (vs distinctly warted).

As stated above, *E. australiense* has similarities with both *Clastoderma* (Clastodermataceae) and *Barbeyella* (Echinosteliaceae). The relationship between *Clastoderma*, *Echinostelium* and *Barbeyella* has been variously interpreted by those who study myxomycetes. The families have long been regarded as closely allied, with Martin and Alexopolous (1969) considering within the order Echinosteliales, *Barbeyella* and *Clastoderma* as sister genera within the Clastodermataceae, and *Echinostelium* assigned to the Echinosteliaceae. However, Kretzschmar *et al.* (2016) proposed a new phylogeny within the Echinosteliales, based on SSU 18S rRNA gene sequences, and showed the polyphyly of the family Clastodermataceae, as *Barbeyella* was more closely related to *E. arboreum* than to *Clastoderma*, while *C. debaryanum* was the earliest branching clade in Echinosteliales. More recently, Clastodermataceae was raised to ordinal level as the Clastodermatales by Leontyev *et al.* (2019) within the superorder Stemonitiidia (vs Echinosteliales in superorder Echinosteliidia), based on gene sequences. With the emergence of an uncharacteristically dark-coloured *Echinostelium*, molecular analysis of this species may help resolve the still uncertain relationships among these groups.

Acknowledgements

We acknowledge the assistance of Don and Joy Williams for hosting the first author's visits to Hi Vallee farm; Dean Ellis, the first author's husband for technical assistance in the field and unwavering support as we journey around the countryside collecting substrate samples to culture myxomycetes; John Huisman (PERTH) for transmitted light photography, macrophotography and helpful comments with the text; Steve Dillon (PERTH) and Yuri Novozhilov - supported by the state task "Biodiversity, ecology, structural and functional features of fungi and fungus-like protists" (122011900033-4) - for SEM imaging; Alex George assisting with Latin nomenclature and providing information on the characteristics of *Banksia* bark, to Mike Hislop and Rob Davis (PERTH) for assistance with identifying the bark substrate, and to the Western Australian Herbarium (PERTH), Department of Biodiversity, Conservation and Attractions for access to their collection and resources.

References

Department of the Environment (2013). *Australia's bioregions (IBRA)*, IBRA7, Commonwealth of Australia. http://www.environment.gov.au/land/nrs/science/ibra#ibra [accessed 10 Aug. 2022].

GBIF Secretariat (2001-2023). *Echinostelium* de Bary. GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei [accessed via GBIF.org on 28 March. 2023].

Haskins, E.F. & Clark, J. (2016). A guide to the biology and taxonomy of the Echinosteliales. *Mycosphere* 7(4): 473–491.

Keller, H.W. & Brooks, T.E. (1976). Corticolous Myxomycetes V: Observations on the genus *Echinostelium*. *Mycologia* 68: 1204–1220.

Knight, K.J. & Lado, C. (2020). *Clastoderma confusum* (Myxomycetes: Amoebozoa), a remarkable new species of slime mould from Western Australia. *Nuytsia* 31: 35–40.

Kowalski, D.T. & Hinchee, A.A. (1971). *Barbeyella minutissima*: a common alpine myxomycete. *Syesis* 5: 95–97.

Kretzschmar, M., Kuhnt, A., Bonkowski, M. & Fiore-Donno, A.M. (2016). Phylogeny of the highly divergent Echinosteliales (Amoebozoa). *Journal of Eukaryotic Microbiology* 63(4): 453–459.

Lado, C. (2005-2023). An on line nomenclatural information system of Eumycetozoa. Real Jardín Botánico, CSIC. Madrid, Spain. https://eumycetozoa.com (28 Mar. 2023).

Leontyev, D.V., Schnittler, M., Stephenson, S.L., Novozhilov, Y.K & Shchepin, O.N. (2019). Towards a phylogenetic classification of the myxomycetes. *Phytotaxa* 399(3): 209–238.

Martin, G.W. & Alexopoulos, C.J. (1969). The Genera of Myxomycetes. (University of Iowa Press: Iowa City.)

McHugh, R., Stephenson, S.L., Mitchell, D.W. & Brims, M.H. (2003). New records of Australian Myxomycota. *New Zealand Journal of Botany* 41: 487–500.

Novozhilov, Y.K., Zemlyanskaya, I., Schnittler, M. & Stephenson S.L. (2006). Myxomycete diversity and ecology in the arid regions of the Lower Volga River Basin (Russia). *Fungal Diversity* 23: 193–241.

Novozhilov, Y.K. & Schnittler, M. (2008). Myxomycete diversity and ecology in arid regions of the Great Lake Basin of western Mongolia. *Fungal Diversity* 30: 97–119.

Novozhilov, Y.K., Erastova, D.A., Shchepin, O.N., Schnittler, M., Aleksandrova, A.V., Popov, E.S. & Kuznetsov, A.N. (2017). Myxomycetes associated with monsoon lowland tropical forests in southern Vietnam. *Nova Hedwigia* 104(1-3): 143–182.

Pando, F. & Oltra, M. (2000). On the spore wall of *Echinostelium elachiston* (Myxomycetes). *Mycotaxon* 74(2): 495–498.

Schnittler, M. & Stephenson, S.L. (2000). Myxomycete biodiversity in four different forest types in Costa Rica. *Mycologia* 92: 626–637.

Stephenson, S.L. (2021). Secretive Slime Moulds, Myxomycetes of Australia. (ABRS: Canberra; CSIRO Publishing: Melbourne).

Western Australian Herbarium (1998–2023). Florabase—the Western Australian Flora. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au/ [accessed 28 Mar. 2023].

Vlasenko, A.V., Filippova N.V. & Vlasenko, V.A. (2018) *Echinostelium novozhilovii* (Echinosteliaceae, Myxomycetes), a new species from Northern Asia. *Phytotaxa* 367(1): 91–96.

Vlasenko, A.V., Filippova N.V. & Vlasenko, V.A. (2019) *Echinostelium microsporum* (Echinosteliaceae, Myxomycetes), a new epiphytic corticolous species from Russia. *Phytotaxa* 416(1): 67–72.

Whitney, K.D. (1980). The myxomycete genus *Echinostelium*. *Mycologia* 72: 950–987.

.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dpaw.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01054

Nuytsia 34: 187–201
Published online 20 July 2023

Volvopluteus earlei and *Volvariella taylorii*: new fungi for Western Australia (Basidiomycota: Agaricales: Pluteaceae)

Neale L. Bougher[1] and Matthew D. Barrett[1,2,3]

[1] Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2]Australian Tropical Herbarium, James Cook University,
McGregor Road, Smithfield, Queensland 4878
[3] Corresponding author, email: matt.barrett@jcu.edu.au

Abstract

Bougher, N.L. & Barrett, M.D. *Volvopluteus earlei* and *Volvariella taylorii*: new fungi for Western Australia (Basidiomycota: Agaricales: Pluteaceae). *Nuytsia* 34: 187–201 (2023). Re-examination of vouchered specimens of pink-spored, volvate, agaricoid fungi held at the Western Australian Herbarium (PERTH) has revealed the first recorded occurrences in Western Australia of *Volvopluteus earlei* (Murrill) Vizzini, Contu & Justo and *Volvariella taylorii* (Berk. & Broome) Singer, and affirmed the regional prevalence of *Volvopluteus gloiocephalus* (DC.) Vizzini, Contu & Justo. The identities of the two *Volvopluteus* Vizzini, Contu & Justo taxa were confirmed with molecular data relative to extra-Australian samples validated in previous studies. *Volvopluteus earlei* had not been previously reported from Australia. Evidently *Volvopluteus earlei* and *Volvariella taylorii* are less common in Australia than the larger and more often encountered Common Rosegill, *Volvopluteus gloiocephalus*.

Introduction

Australian members of the mushroom family Pluteaceae mostly have not been critically re-evaluated since the advent of the DNA revolution in the 1990s, nor in light of the family-wide phylogeny-based revisions of the family by Justo *et al*. (2011a, b) and others. Only a few Australian samples of *Melanoleuca* Pat. and *Pluteus* Fr. have been included in published studies (Bougher & Barrett 2020; Holec *et al*. 2018; Ševčíková *et al*. 2021). The present study considers three species in the genera *Volvopluteus* Vizzini, Contu & Justo and *Volvariella* Speg. with putative global distributions. These are mushroom-like fungi with a thick veil that envelops the egg-like immature stage and later forms a cup-like volva at the base of the stipe, free pinkish lamellae, and a salmon-coloured spore deposit. All such fungi were traditionally placed under *Volvariella* until molecular phylogenetic studies necessitated the segregation of some species into a newly elevated genus *Volvopluteus* (Justo *et al.* 2011a, b). *Volvariella* and *Volvopluteus* are well distinguished morphologically. Species of *Volvopluteus* have large spores and a gelatinised pileus whereas species of *Volvariella* mostly have shorter spores and a non-gelatinised pileus. Both genera are placed in the family Pluteaceae, in the order Agaricales (e.g. Kalichman *et al*. 2020), although some studies support the placement of *Volvariella* outside the Pluteoid clade (e.g. Justo *et al*. 2011b).

At the onset of the present study, pink-spored, volvate fungi collected in Western Australia (WA) held

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

as vouchered specimens at the Western Australian Herbarium (PERTH) were: *Volvariella bombycina* (Schaeff.) Singer (1 collection), *Volvariella* cf. *media* (Schumach.) Singer (3), *Volvariella* sp. (6), and *Volvopluteus gloiocephalus* (DC.) Vizzini, Contu & Justo (24) (Table 1). We re-examined these collections (all from southern WA) with a view to reviewing their identity. An additional collection of a volvarioid fungus (from northern WA) was also studied prior to its lodgement and incorporation at PERTH.

Materials and methods

Morphology

Morphological attributes of vouchered specimens of pink-spored, volvate fungi collected in WA and held at PERTH were studied (Table 1). The micromorphology of hand-sectioned dried material rehydrated in 3% KOH was examined by light microscopy using a Nikon 80i compound microscope. For spores, the abbreviation x refers to the mean length × mean width, Q refers to the length/width ratio and Qx refers to the mean ratio measured from n basidiospores, observed from p collections. Colour notations in descriptions are from Kornerup and Wanscher (1978) by plate and row number.

DNA isolation, PCR amplification and DNA sequencing

The Internal Transcribed Spacer (ITS) and Large Subunit (nLSU) of nuclear ribosomal DNA were sequenced for selected samples using the methodology described in Bougher and Barrett (2020). DNA sequences were compiled with relevant GenBank accessions included in previous studies (Table 2), and aligned using the MAFFT algorithm, implemented in Geneious Prime® v. 2021.2.2 (Kearse *et al*. 2012). Phylogenetic trees were reconstructed from the concatenated ITSn+LSU alignment using RAxML algorithm (Stamatakis 2014), using a rapid bootstrapping and search algorithm with 100 bootstrap replicates and a GTR+GAMMA nucleotide substitution model, as embedded in Geneious Prime v2021.2.2 (https://www.geneious.com; Kearse *et al.* 2012). The nucleotide substitution model was chosen using jModeltest 2 (Darriba *et al.* 2012).

Table 1. Morphological identities of pink-spored, volvate fungi collected in Western Australia and held prior to this study at the Western Australian Herbarium (PERTH). PERTH collections identified prior to this study as *Volvariella gloiocephalus* are not included in this table. *Collections cited as *Volvariella speciosa* (Fr.) Singer by Hilton (1982). **Voucher specimen recently lodged at PERTH.

PERTH	Coll. date	Location	Prior identification	Reviewed identification
00750425	3/08/1964	Kings Park, Perth	*Volvariella* sp.*	*Volvopluteus gloiocephalus*
00752983	1/07/1967	Condingup	*Volvariella* sp.	*Amanita* sp.
00759392	18/07/1971	Subiaco, Perth	*Volvariella bombycina*	*Volvopluteus gloiocephalus*
00761427	Aug. 1971	Esperance	*Volvariella* sp.*	*Volvopluteus gloiocephalus*
00767212	18/06/1973	Esperance	*Volvariella* sp.	*Volvopluteus gloiocephalus*
07572689	22/02/1998	City Beach, Perth	*Volvariella* ? sp.	*Volvopluteus earlei*
07680279	2/03/2005	Scarborough, Perth	*Volvariella* cf. *media*	*Volvopluteus earlei*
07680287	6/03/2005	Scarborough, Perth	*Volvariella* cf. *media*	*Volvopluteus earlei*
07680295	8/03/2005	Scarborough, Perth	*Volvariella* cf. *media*	*Volvopluteus earlei*
09519432**	14/02/2011	Broome	*Volvariella* sp.	*Volvopluteus earlei*
07552440	15/06/1995	Kellerberrin	*Volvariella* sp.	*Volvariella taylorii*

Table 2. Accessions used in the molecular phylogeny. nLSU sequences contiguous with ITS are indicated in brackets.

Taxon	Voucher origin	Voucher/ strain	ITS GenBank	nLSU GenBank	Reference
Volvopluteus earlei	Pakistan	LAH35715	MW362280		Kahn *et al.* (2022)
Volvopluteus earlei	Turkey: Bursa	OKA-TR656	MW033396	MW029827	Kaygusuz *et al.* (2021)
Volvopluteus earlei	Turkey: Izmir	OKA-TR655	MW033395	MW029826	Kaygusuz *et al.* (2021)
Volvopluteus earlei	Turkey: Mersin	OKA-TR654	MW033394	MW029825	Kaygusuz *et al.* (2021)
Volvopluteus earlei	Democratic Republic of the Congo	Mamet7	HM562205		Justo *et al.* (2011a)
Volvopluteus earlei (as *Volvariella cookei*)	Italy: Sardinia	TO AV133	HM246496	HM246480	Justo *et al.* (2011a)
Volvopluteus earlei	Spain	MA22816	HM562204	HM562253	Justo *et al.* (2011a)
Volvopluteus earlei	Italy: Lucca	ALV17724	MK204987		Giannoni *et al.* (2018)
Volvopluteus earlei (as *Volvariella media*)	Italy: Sardinia	TO HG2001	HM246498		Justo *et al.* (2011a)
Volvopluteus earlei	Italy: Sardinia	TO AV134	HM246497	HM246482	Justo *et al.* (2011a)
Volvopluteus earlei	Italy: Lucca	ALV17726	MK204989		Giannoni *et al.* (2018)
Volvopluteus earlei	Italy: Lucca	ALV17725	MK204988		Giannoni *et al.* (2018)
Volvopluteus earlei (as *Volvariella acystidiata*)	Italy: Sardinia	TO HG1973	HM246499	HM246481	Justo *et al.* (2011a)
Volvopluteus earlei	China	XJ1379	MW811446		J. Xu, unpublished
Volvopluteus earlei	China	XJ1378	MW811445		J. Xu, unpublished
Volvopluteus earlei	Japan: Niigata	Kasuya B3518, TNS:F-70427	MH021868		Kasuya *et al.* (2018)
Volvopluteus earlei	Japan: Chiba	Kasuya B3561, TNS:F-70428	MH021869		Kasuya *et al.* (2018)
Volvopluteus sp.	China: Xinjiang	JPL-2019, GDGM73195	MK944281	MN056508	Chuan-Hua, L. *et al.*, unpublished
Volvopluteus sp.	China: Xinjiang	JPL-2019, GDGM74751	MK944280	MN056509	Chuan-Hua, L. *et al.*, unpublished
Volvopluteus asiaticus	Japan	TNSF15191; from TYPE material	HM562206		Justo *et al.* (2011a)
Volvopluteus asiaticus	China	HD2022	OP599925		Y. Yang, unpublished

Taxon	**Voucher origin**	**Voucher/ strain**	**ITS GenBank**	**nLSU GenBank**	**Reference**
Volvopluteus asiaticus	China	HD2021	OP597804		Y. Yang, unpublished
Volvopluteus michiganensis	Russia	LE 312006	MK729542		Krom *et al.* (2019)
Volvopluteus michiganensis	Russia: Krasnoyarsky Kray	LE311991	MK049912		Krom *et al.* (2019)
Volvopluteus michiganensis	China	HMJAU-CR106	MW242669		Rao *et al.* (2021)
Volvopluteus michiganensis	USA: Michigan	A.H. Smith 32-590 (MICH 11761); from TYPE material	HM562195 (duplicate record NR_11987)		Justo *et al.* (2011a)
Volvopluteus michiganensis	Canada: AB, Helena Lakes	UBC F-32158	MF954699		Berbee, M.L. *et al.*, unpublished
Volvopluteus sp.	Iran: Tehran	Ghobad-Nejhad 4321	MT535739	MT554328	Ghobad-Nejhad *et al.* (2020)
Volvopluteus michiganensis	Russia	LE311989	MK729541		Krom *et al.* (2019)
Volvopluteus gloiocephalus	Denmark	DM1042	MT644914		Leerhoei, F. & Langkjaer, E.M, unpublished
Volvopluteus gloiocephalus	Russia	5173	MH930216		Vaishlya, O.B. *et al.*, unpublished
Volvopluteus gloiocephalus	Egypt	EGDA-Volv1	MW916608		El-Gharabawy, H.M. & El-Fallal, A.A., unpublished
Volvopluteus gloiocephalus	Turkey: Hatay	OKA-TR666	MW033406	MW029837	Kaygusuz *et. al.* (2021)
Volvopluteus gloiocephalus	Turkey: Aydin	OKA-TR665	MW033405	MW029836	Kaygusuz *et. al.* (2021)
Volvopluteus gloiocephalus	Turkey: Bursa	OKA-TR664	MW033404	MW029835	Kaygusuz *et. al.* (2021)
Volvopluteus gloiocephalus	Turkey: Afyonkarahisar	OKA-TR663	MW033403	MW029834	Kaygusuz *et. al.* (2021)
Volvopluteus gloiocephalus	New Zealand	PDD_103792	MN738645	MN738593	Cooper, J.A., unpublished
Volvopluteus gloiocephalus	Algeria: M'Sila forest	CM042	KP826741		Benazza, M. *et al.*, unpublished
Volvopluteus gloiocephalus	USA: Arizona	Mushroom Observer 420468	MW633065		Clements, T.A., unpublished
Volvopluteus gloiocephalus	Spain	LOU18247	HM562209		Justo *et al.* (2011a)

Taxon	Voucher origin	Voucher/ strain	ITS GenBank	nLSU GenBank	Reference
Volvopluteus gloiocephalus	Spain	LOU13710	HM562208		Justo *et al.* (2011a)
Volvopluteus gloiocephalus	Portugal	LOU18619	HM562207		Justo *et al.* (2011a)
Volvopluteus gloiocephalus	Spain	AJ239	HM562202	HM562252	Justo *et al.* (2011a)
Volvopluteus gloiocephalus (as *V. gloiocephala*)	Italy: Sardinia	TO AV135	HM246490	HM246476	Justo *et al.* (2011a)
Volvopluteus gloiocephalus	USA: California	PBM2272	HM562203		Justo *et al.* (2011a)
Volvopluteus gloiocephalus	New Zealand	JAC10832	MN738634	MN738571	Cooper, J.A., unpublished
Volvopluteus gloiocephalus	Canada: BC, New Westminster	UBC F-32227	MF954700		Berbee, M.L. *et al.*, unpublished
Volvopluteus gloiocephalus	USA: California	MO479337	OP470065		Schwartz, J. *et al.*, unpublished
Volvariella gloiocephalus (as *V. gloiocephala*)	Italy: Sardinia	TO AV136	HM246495	HM246478	Justo *et al.* (2011a)
Volvopluteus gloiocephalus (as *Vp.* sp.)	Iran: Zanjan	12	MK785230		Ammarellou, A. & Alvarado, P., unpublished
Volvariella gloiocephala	USA: California	AFTOL-ID 890, PBM2272	DQ494701	AY745710	Matheny *et al.* (2006)
Volvopluteus gloiocephalus	Australia: WA, Wembley Downs	*N.L. Bougher* NLB 1579, PERTH 08945233	**OP809559**	**(OP809559)**	**This study**
Volvopluteus earlei	Australia: WA, near Broome	*M.D. Barrett* F86/11, PERTH 09519432	**OP809558**	**OP808462**	**This study**
Volvopluteus earlei	Australia: NT, near Katherine	*M.D. Barrett* F14/10, DNA D0290038	**OP809557**	**OP808461**	**This study**
Pluteus romellii	Australia: WA, Kings Park	*N.L. Bougher* NLB 1554, PERTH 08944962	MT537114	(MT537114)	Bougher & Barrett (2020)
Pluteus terricola	New Zealand	JAC14632, PDD:106511	MN738653	MN738580	Cooper, J.A., unpublished
Pluteus multiformis	Spain	X472	MN250225		Ševčíková *et al.* (2021)

Results

PERTH collections labelled as *Volvopluteus gloiocephalus*

All 24 PERTH collections labelled as *Volvopluteus gloiocephalus* were confirmed as correctly identified.

PERTH collections labelled other than as *Volvopluteus gloiocephalus*

Four of the five collections from the 1960s and 1970s that had been referred to *Volvariella* were found to match *Volvopluteus gloiocephalus* (Table 1) by virtue of their large spores, cystidia forms, and a highly gelatinised pileipellis. One of these collections (PERTH 00759392, from Subiaco in 1971) had been previously identified as *V. bombycina*, a lignicolous (wood-inhabiting) species with a non-gelatinised pileipellis. This material, which consists of a single, immature specimen that lacks spores, shows no evidence of a lignicolous habit and has a broad ixocutis. Both of these features are indicative of *Volvopluteus gloiocephalus*. The fifth collection (PERTH 00752983, from Condingup in 1967) has smooth, hyaline spores, and velar tissue with some inflated cells, features typical of *Amanita* Pers.

A collection from City Beach in 1998 labelled as *Volvariella* ? sp. and three collections from Scarborough in 2005 previously identified as *Volvariella* cf. *media* are referable to *Volvopluteus earlei* (Murrill) Vizzini, Contu & Justo (Table 1) on account of their small white basidiomata, large spores, variably-shaped cystidia, and gelatinised pileipellis. A collection from Broome in 2011 was also morphologically confirmed as *V. earlei* and subsequently lodged (PERTH 09519432).

A collection from near Kellerberrin in 1995 (PERTH 07552440) previously identified as *Volvariella* sp. morphologically conforms with *Volvariella taylorii* (Berk. & Broome) Singer based on features such as its small, grey, radially fibrillose pileus, grey volva, ellipsoid-ovoid to oblong spores, cystidia forms, and non-gelatinised pileipellis.

Molecular identities of *Volvopluteus* species

The RAxML analysis of concatenated ribosomal sequences from ITS and nLSU confirmed the identities of the two Australian *Volvopluteus* species (Figure 1). The two tropical Australian collections (from Broome, WA and the Northern Territory) were strongly supported as belonging to a clade containing all samples of *V. earlei* from other continents. The single southern Australian accession of *V. gloiocephalus* was strongly supported as belonging to a clade containing all other *V. gloiocephalus* from other continents. Both species are thus confirmed to be present in Australia, and belong to the same ribosomal lineages as present on multiple continents. The morphological species concepts of both species of *Volvopluteus* applied here are thus confirmed consistent with their global distributions.

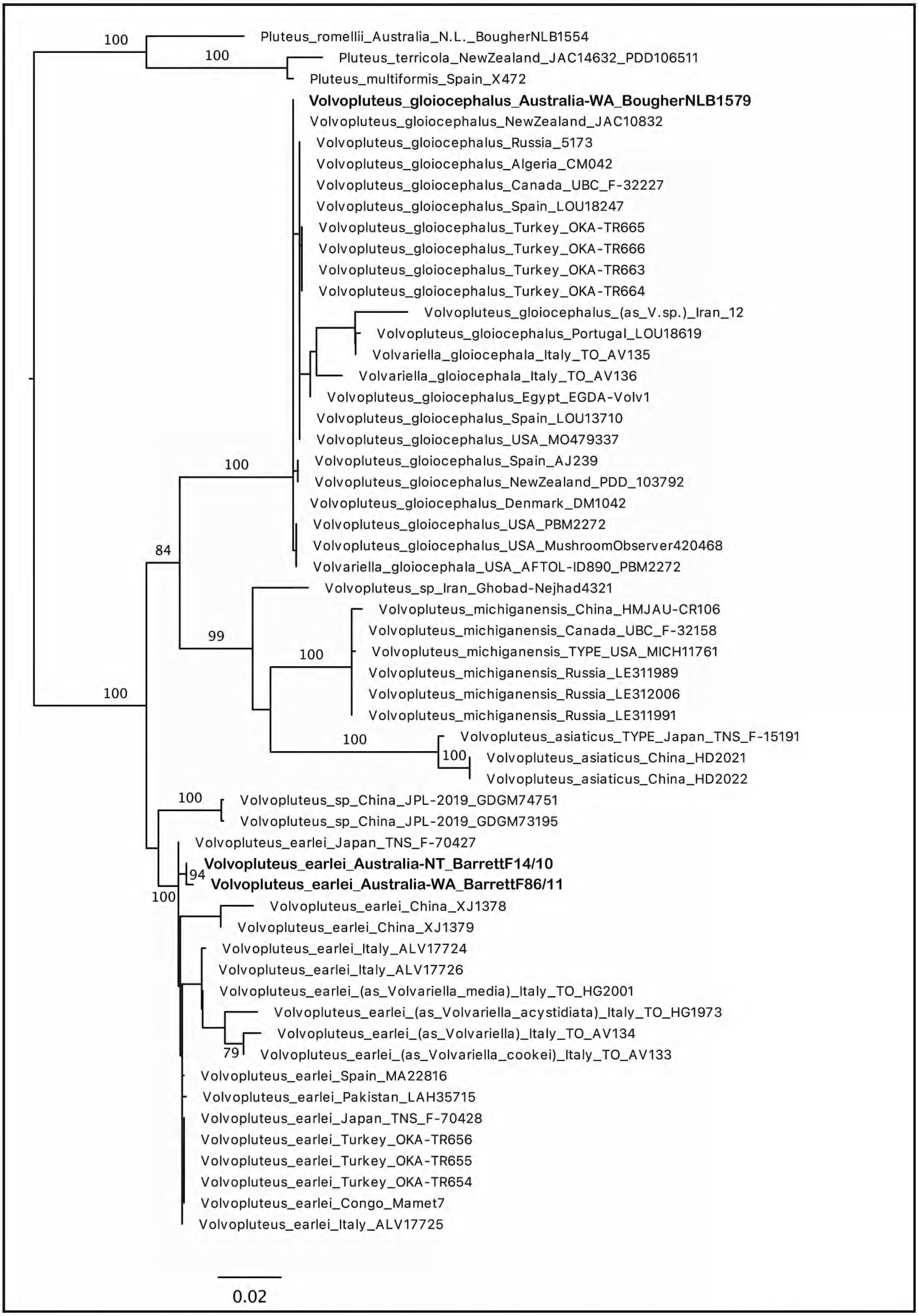
100
Pluteus_romellii_Australia_N.L._BougherNLB1554
100
Pluteus_terricola_NewZealand_JAC14632_PDD106511
Pluteus_multiformis_Spain_X472
Volvopluteus_gloiocephalus_Australia-WA_BougherNLB1579
Volvopluteus_gloiocephalus_NewZealand_JAC10832
Volvopluteus_gloiocephalus_Russia_5173
Volvopluteus_gloiocephalus_Algeria_CM042
Volvopluteus_gloiocephalus_Canada_UBC_F-32227
Volvopluteus_gloiocephalus_Spain_LOU18247
Volvopluteus_gloiocephalus_Turkey_OKA-TR665
Volvopluteus_gloiocephalus_Turkey_OKA-TR666
Volvopluteus_gloiocephalus_Turkey_OKA-TR663
Volvopluteus_gloiocephalus_Turkey_OKA-TR664
Volvopluteus_gloiocephalus_(as_V.sp.)_Iran_12
Volvopluteus_gloiocephalus_Portugal_LOU18619
Volvariella_gloiocephala_Italy_TO_AV135
Volvariella_gloiocephala_Italy_TO_AV136
Volvopluteus_gloiocephalus_Egypt_EGDA-Volv1
Volvopluteus_gloiocephalus_Spain_LOU13710
Volvopluteus_gloiocephalus_USA_MO479337
100
Volvopluteus_gloiocephalus_Spain_AJ239
Volvopluteus_gloiocephalus_NewZealand_PDD_103792
Volvopluteus_gloiocephalus_Denmark_DM1042
Volvopluteus_gloiocephalus_USA_PBM2272
84
Volvopluteus_gloiocephalus_USA_MushroomObserver420468
Volvariella_gloiocephala_USA_AFTOL-ID890_PBM2272
Volvopluteus_sp_Iran_Ghobad-Nejhad4321
Volvopluteus_michiganensis_China_HMJAU-CR106
Volvopluteus_michiganensis_Canada_UBC_F-32158
99
100
Volvopluteus_michiganensis_TYPE_USA_MICH11761
Volvopluteus_michiganensis_Russia_LE311989
100
Volvopluteus_michiganensis_Russia_LE312006
Volvopluteus_michiganensis_Russia_LE311991
100
Volvopluteus_asiaticus_TYPE_Japan_TNS_F-15191
100
Volvopluteus_asiaticus_China_HD2021
Volvopluteus_asiaticus_China_HD2022
100
Volvopluteus_sp_China_JPL-2019_GDGM74751
Volvopluteus_sp_China_JPL-2019_GDGM73195
Volvopluteus_earlei_Japan_TNS_F-70427
Volvopluteus_earlei_Australia-NT_BarrettF14/10
94
Volvopluteus_earlei_Australia-WA_BarrettF86/11
100
Volvopluteus_earlei_China_XJ1378
Volvopluteus_earlei_China_XJ1379
Volvopluteus_earlei_Italy_ALV17724
Volvopluteus_earlei_Italy_ALV17726
Volvopluteus_earlei_(as_Volvariella_media)_Italy_TO_HG2001
Volvopluteus_earlei_(as_Volvariella_acystidiata)_Italy_TO_HG1973
Volvopluteus_earlei_(as_Volvariella)_Italy_TO_AV134
79
Volvopluteus_earlei_(as_Volvariella_cookei)_Italy_TO_AV133
Volvopluteus_earlei_Spain_MA22816
Volvopluteus_earlei_Pakistan_LAH35715
Volvopluteus_earlei_Japan_TNS_F-70428
Volvopluteus_earlei_Turkey_OKA-TR656
Volvopluteus_earlei_Turkey_OKA-TR655
Volvopluteus_earlei_Turkey_OKA-TR654
Volvopluteus_earlei_Congo_Mamet7
Volvopluteus_earlei_Italy_ALV17725
0.02

Figure 1. Phylogenetic placement of Australian *Volvopluteus* samples (indicated in bold) amongst globally representative samples. RAxML tree with support values from 100 bootstrap replicates.

Taxonomy

Volvopluteus gloiocephalus (DC.) Vizzini, Contu & Justo, in Justo, A., Vizzini, A., Minnis, A.M., Menolli, N. Jr. , Capelari, M., Rodrıguez, O., Malysheva, E., Contu, M., Ghignone, S. & Hibbett, D.S., *Fungal Biology* 115(1): 15 (2011).

≡ *Agaricus gloiocephalus* DC., *Fl. franç*. 5/6: 52 (1815).

[*Volvariella speciosa auct. non* (Fr.) Singer: Bougher & Syme (1998: 226).]

Pileus 30–110 mm wide, ovoid at unexpanded stage, conico-convex when young, soon developing an umbo and expanding to flat, uniformly greyish beige (2A2–3A2) except darker brownish (5C5) at the umbo, thick-viscid or more often thick-glutinous (not very sticky), drying shiny-smooth; margin incurved and entire, then plane and eroded when old, entire and translucent-striate close to margin. *Lamellae* free, up to 16 mm deep, crowded, white in button stage, soon beige (2A2), then pink and finally brownish pink (6D6); edge minutely fringed, very eroded with age; 1 or 2 tiers of lamellulae. *Stipe* 35–120 × 5–22 mm, cylindrical or tapering upwards, solid or partially hollow, dry, white tinged yellowish or brownish (4B4), with long striate, silky fibrils, and sometimes with minute white floccules near base of stem. *Volva* usually buried in soil, saccate, white, with a free limb up to 1 mm thick, no veil remnants on cap. *Context* white, sometimes dulling with age and watery when old. *Odour* not distinctive. *Taste* none, indistinct. (Figure 2A)

Basidiospores pink-brown (near 7D7) in deposit, pale yellow-brown in water or KOH, (10.5) 12–17.5 × 7.5–10 µm, x = 14.9 × 8.7 µ, Q = 1.55–1.93, Qx = 1.72 (n = 50, p = 1), not dextrinoid or amyloid, ellipsoid, smooth, thick-walled (up to 1 µm), germ pore absent. *Basidia* 42–56 × 12–16 µm, cylindro-clavate to clavate, 4-spored, sterigmata up to 5 µm long. *Cheilocystidia* 32–70 × 10–25 µm, mainly fusoid-ventricose, some more swollen or clavate, with or without a narrow apical extension (2–3 × up to 18 µm). *Pleurocystidia* 45–60 × 20–40 µm, clavate, ventricose, some with short rostrum up to 5 µm long, scattered. *Pileipellis* with a broad outer layer of dissolved, hyaline hyphae embedded in a gelatinous matrix; hyphae in lower pellis with intact walls 6–10 µm broad, smooth, hyaline. *Clamp connections* absent. (Figure 3A–C)

Selected specimens [28 PERTH collections examined]. WESTERN AUSTRALIA: Colin Road, Wembley Downs, emerging in leafy mulched garden bed, 21 Aug. 2017, *N.L. Bougher* NLB 1579 (PERTH 08945233; ITS/LSU sequence GenBank OP809559); Woodlake Retirement Home, Woodlake Retreat, Kingsley, Perth, in garden bed with woodchips and rich mulch, 15 Aug. 2009, *N.L. Bougher & M. Bougher* BOU 00571 (PERTH 08473927); Wellington Street, Albany, in composted hay, 19 May 1993, *K. Syme* KS 642/93 (PERTH 05506301).

Notes. This is a common and conspicuous species in gardens, parks and farms throughout southern Australia. It is readily recognised by its large basidiomata with a slimy to sticky pileus, dull pink mature lamellae, and tall white stipe lacking a ring and with a basal cup-like volva. In WA, as elsewhere, its basidiomata may occur singly or extensively in large numbers, and are usually found in disturbed areas rich in organic matter, e.g. mulched garden beds, woodchip beds, composted hay, or areas of mowed or unkempt grass. The ITS/LSU sequence of a typical collection from the Perth region (PERTH 08945233) has 100% similarity with sequences of *V. gloiocephalus* on GenBank (Figure 1).

The above description has been adapted from that presented in Bougher and Syme (1998, as *Volvariella speciosa* (Fr.) Singer), which was based on a Western Australian collection (PERTH 05506301).

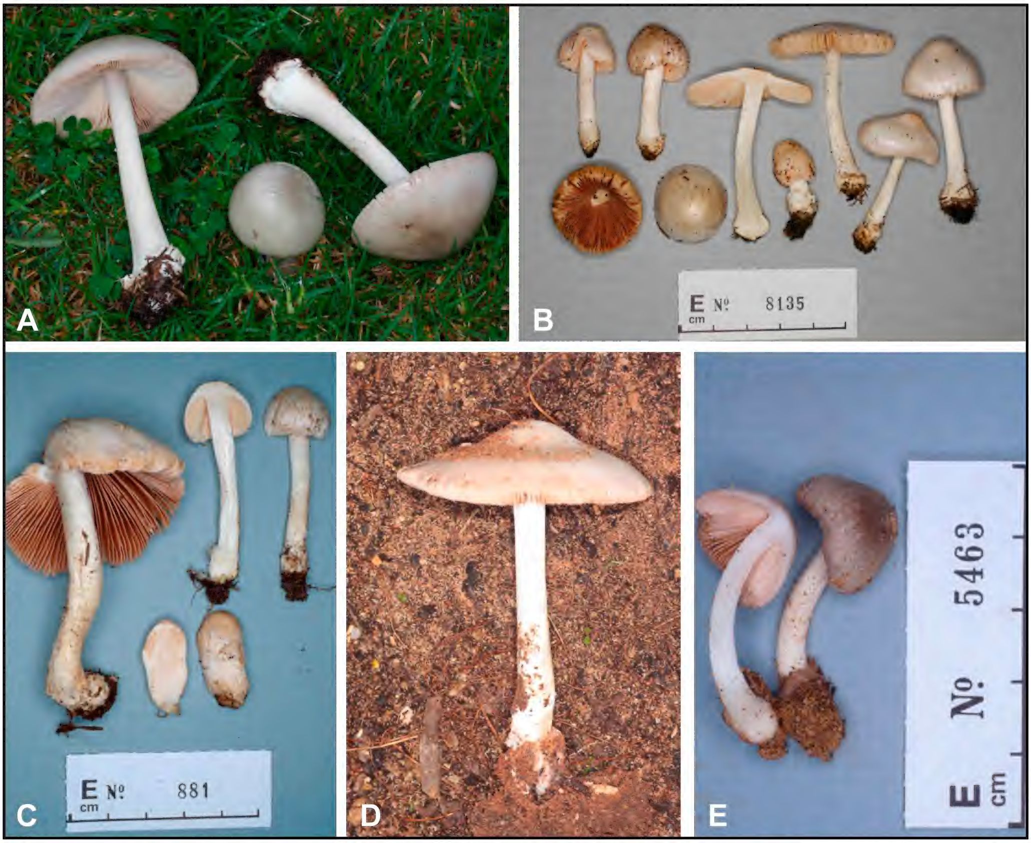

Figure 2. Basidiomata. A – *Volvopluteus gloiocephalus* (PERTH 08473927); B – *Volvopluteus earlei* (PERTH 07680287); C – *Volvopluteus earlei* (PERTH 07572689); D – *Volvopluteus earlei* (PERTH 09519432); E – *Volvariella taylorii* (PERTH 07552440). Scale bars = 2 cm.

Volvopluteus earlei (Murrill) Vizzini, Contu & Justo, in Justo, A., Vizzini, A., Minnis, A.M., Menolli, N. Jr. , Capelari, M., Rodrıguez, O., Malysheva, E., Contu, M., Ghignone, S. & Hibbett, D.S., *Fungal Biology* 115(1): 15 (2011).

≡ *Volvariopsis earlei* Murrill, *Mycologia* 3(6): 282 (1911).

Pileus 20–50 (80) mm wide, initially hemispherical or conic, expanding to bluntly conic-campanulate with or without a low umbo, finally plane or undulate, white to cream to almost snow-white, dulling with age then becoming slightly darker or pale yellowish biscuit in centre (near to but paler than 4A–B2); margin decurved then plane, becoming thin-fleshed at the extreme margin often exposing the lamellae, may become deeply split; pileus surface viscid-sticky in wet conditions, slippery as becoming drier, shiny and minutely radially appressed silky fibrillose in dry conditions. *Lamellae* free, densely crowded to subcrowded, ventricose, white when very young then cream becoming pale apricot-pink (4A2), then darker pink (6A2–6A3), then dark dull brown-pink (7C5, 7C6) at maturity, up to 5 mm deep; edge smooth, concolorous and entire, lamellulae in one series. *Stipe* 40–70 (100) × 5–10 mm, white, cylindric or tapering slightly towards apex, base rounded to clavate; surface dry, shiny, smooth to the eye but longitudinally appressed silky fibrillose (under lens); annulus absent. *Volva* 21–32 × 15–25 mm, sheathing, white, membranous, saccate with a narrow free rim, often less

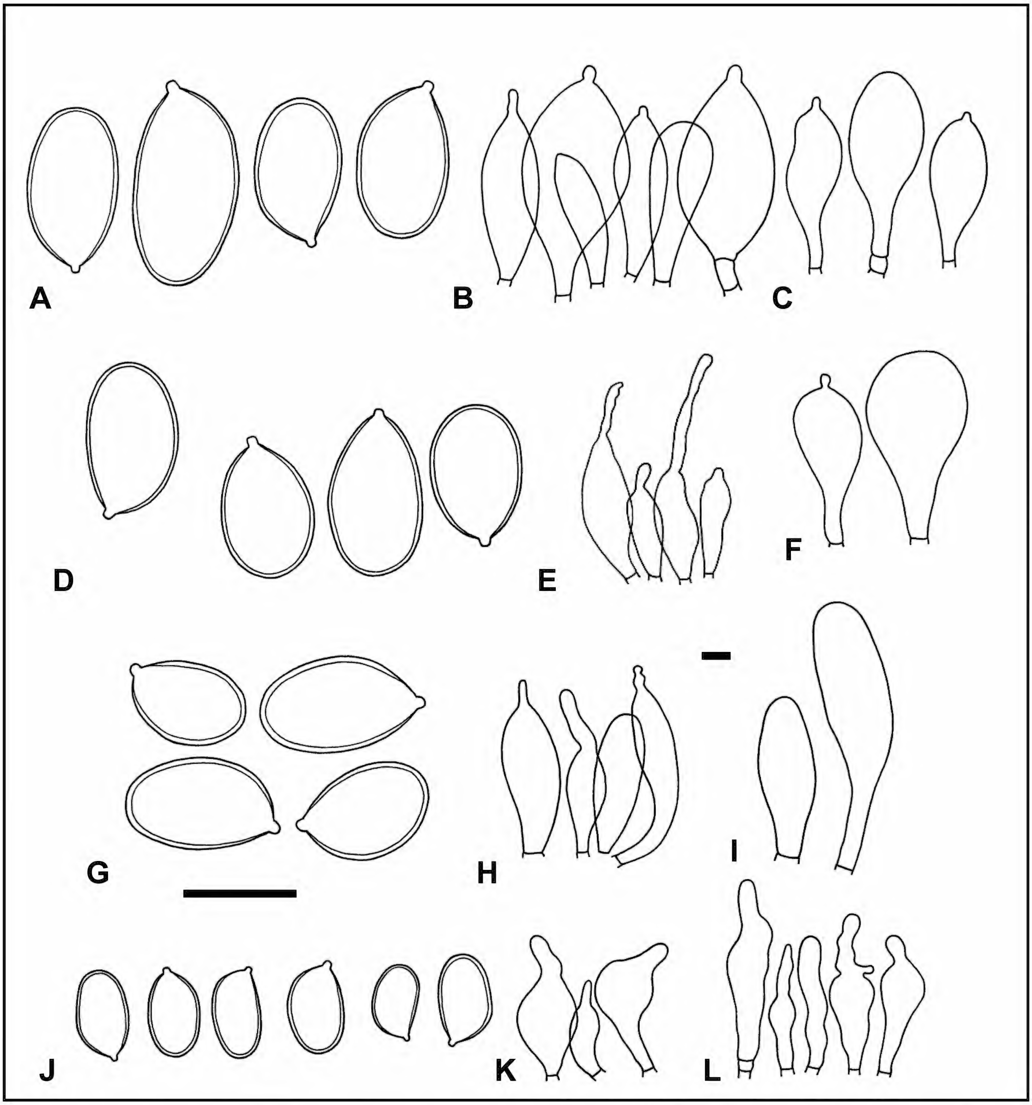

Figure 3. Micromorphology. A–C, *Volvopluteus gloiocephalus* (PERTH 08473927): A – spores; B – cheilocystidia; C – pleurocystidia. D–F, *Volvopluteus earlei* (PERTH 07572689): D – spores; E – cheilocystidia; F – pleurocystidia. G–I, *Volvopluteus earlei* (PERTH 09519432): G – spores; H – cheilocystidia; I – pleurocystidia. J–L, *Volvariella taylorii* (PERTH 07552440): J – spores; K – cheilocystidia; L – pleurocystidia. Scale bars = 10 µm (longer bar spores, shorter bar cystidia).

conspicuous in mature specimens as the rim may become appressed to the stipe with age. *Context* white in pileus and stipe, stipe solid eventually becoming densely longitudinally fibrous/stuffed or developing a thin hollow centre with age, not staining or bruising. *Odour* fabaceous (fresh beans), or cooked fresh sweet corn, or not noticeable. (Figure 2B–D)

Basidiospores dark orangish pink or brownish pink or deep salmon pink-brown (near 6-7C–D7–7E7) in deposit, pale yellowish in water or KOH, PERTH 07680287: 12–15.5 × 7.3–9.5 µm, x = 13.5 × 8.4 µm, Q = 1.47–1.92, Qx = 1.63 (n = 50, p = 2), PERTH 09519432: 10.5–14.7 × 6.8–8.9 µm, x = 11.8 × 7.5 µm, Q = 1.46–1.71, Qx = 1.58 (n = 27, p = 1), ellipsoid, smooth, thick-walled, apiculus prominent. *Basidia* 35–51 × 10–14 µm, clavate to cylindro-clavate, hyaline, mostly 4-sterigmate, rarely 2-sterigmate. *Cheilocystidia* 30–75 × 11–24 µm, variable in shape – clavate, ellipsoid, fusoid, ventricose or lageniform, with or without apical extension up to 12 µm long (rarely up to 45 µm long), smooth, thin-walled, hyaline, often abundant and crowded. *Pleurocystidia* 31–85 × 15–38 µm, clavate to cylindro-clavate or vesiculose, sometimes with an apical extension, smooth, thin-walled, sometimes thickened in upper part, hyaline, inconsistently present (scattered singly, rare or absent). *Pileipellis* a narrow ixocutis of gelatinised hyphal remnants, overlying a cutis of non-gelatinised hyaline hyphae 3–7 µm wide. *Caulocystidia* none observed. *Clamp connections* absent. (Figure 3D–I)

Specimens examined. WESTERN AUSTRALIA: North end of Cable Beach, Broome, in pile of dirt and mulch used for garden landscaping, 14 Feb. 2011, *M.D. Barrett* F86/11 (PERTH 09519432; ITS sequence GenBank OP809558; LSU sequence GenBank OP808462); Yaltara Park, City Beach, Perth, on lawn/grass, 22 Feb. 1998, *N.L. Bougher & M.E. Bougher s.n.* (PERTH 07572689); Drabble-Cobb Park, Scarborough, Perth, scattered on and embedded in grass, 2 Mar. 2005, *N.L. Bougher, M. Bougher & R. Bougher* E 8134 (PERTH 07680279); *loc. id*., 6 Mar. 2005, *N.L. Bougher, M. Bougher & R. Bougher* E 8135 (PERTH 07680287); *loc. id.*, 8 Mar. 2005, *N.L. Bougher, M. Bougher & R. Bougher* E 8136 (PERTH 07680295).

Notes. The specimens described here from WA conform well to *V. earlei* (e.g. as described by Justo & Castro 2010) by virtue of the following morphological features: small, white basidiomata with pilei usually < 50 mm wide, large spores (> 10 µm long), variably-shaped hymenial cystidia sometimes with an apical mucro or longer finger-like appendage, and a gelatinised pileipellis. All the WA collections examined have at least some lageniform cheilocystidia, and some rostrate pleurocystidia occur in the southern WA collections. *Volvopluteus asiaticus* Justo & Minnis has predominantly lageniform cheilocystidia and mostly rostrate pleurocystidia (Justo *et al.* 2011b). However, that species differs from *V. earlei* by having larger basidiomata (pileus > 5 cm diam.). The collection from Broome (F86/11; PERTH 09519432) conforms to sequences (ITS 99% similarity) of *V. earlei* on GenBank and belongs to the same phylogenetic lineage as representatives of that species from other continents (Figure 1).

Volvariella taylorii (Berk. & Broome) Singer [as '*taylori*'], *Lilloa* 22: 401 (1951) [1949].

≡ *Agaricus taylorii* Berk. & Broome, *Ann. Mag. Nat. Hist*., Ser. 2 13: 398 (1854).

Pileus 16 mm wide, convex, margin decurved; surface dry and radially appressed silky fibrillose, dark grey (near 5D2) at centre grading paler grey towards margin (near 5B3). *Lamellae* free, crowded, not ventricose, 2.5 mm deep; pale pink (near 5A3–6A2), edge smooth, concolorous and entire. *Stipe* 30 × 4 mm; cylindrical, base slightly swollen; surface dry, minutely longitudinally appressed silky fibrillose (under lens); entirely white. *Volva* grey (near 5D2), membranous, saccate with a narrow free ragged rim. *Context* white in pileus and stipe, stipe solid, not staining or bruising. *Odour* not distinctive. (Figure 2E)

Basidiospores reddish brown (near 6D6) in deposit, pale yellowish in water or KOH, 7–8.3 × 4.2–5 µm, $x = 7.6 \times 4.6$ µm, $Q = 1.52–1.84$, $Qx = 1.66$ ($n = 27, p = 1$), ellipsoid or ovoid (broadest towards base) to oblong, smooth, thick-walled, apiculus prominent. *Basidia* 21–36 × 8–10 µm, slender clavate, hyaline, 4-sterigmate. *Cheilocystidia* 31–53 × 9–20 µm, ventricose with blunt mucro < 5 µm long or an apical appendage up to 15 × 9 µm, smooth, thin-walled, hyaline or glassy, scattered singly or in small groups. *Pleurocystidia* 40–70 × 10–20 µm, clavate to sublageniform, mostly with a finger-like or sometimes branched apical appendage up to 10–20 × 5–7 µm, smooth, thin-walled, hyaline or glassy, scattered singly. *Pileipellis* a non-gelatinised cutis of hyphae 6–40 µm wide giving rise to emerging mostly undifferentiated or sometimes tapering hyphal-like end-cells, larger inner hyphae often have constricted septa and some end-cells swollen up to 60 µm wide. *Caulocystidia* none observed. *Clamp connections* absent. (Figure 3J–L)

Specimens examined. WESTERN AUSTRALIA: Hilltop site between Site 17A & B, Higginson Rd, 16 km along Bencubbin-Kellerberrin Rd, N of Kellerberrin, single specimen on soil under *Allocasuarina campestris* and *Acacia acuminata*, 15 June 1995, *B. Dunstan & I.C. Tommerup s.n.* (PERTH 07552440).

Notes. This collection from WA's Avon Wheatbelt bioregion conforms with *V. taylorii* as described from other regions of the world (e.g. Pradeep *et al.* 1998 – India; Seok *et al.* 2002 – South Korea). Conforming features include its small, grey, radially fibrillose pileus, grey volva, terrestrial habit, ellipsoid-ovoid to oblong spores 7–8.3 × 4.2–5 µm, hymenial cystidia with an apical appendage (sometimes branched), and non-gelatinised pileipellis with emerging undifferentiated end cells. The identification of this collection as *V. taylorii*, herein based on morphology, remains to be confirmed with molecular data.

Discussion

It is unsurprising that most of the PERTH collections of pink-spored, volvate fungi are of *Volvopluteus gloiocephalus* as this is a very common and conspicuous species aptly known locally as the 'Common Rosegill'. It is also unsurprising that one of the collections originally identified as *Volvariella* is a species of *Amanita*. Many *Amanita* species have a conspicuous, cup-like volva and a few have pink gills, e.g. *A. carneiphylla* O.K. Mill. In addition to having a universal veil, most *Amanita* species produce a white or cream spore deposit. Therefore they are readily distinguishable from species of *Volvariella* and *Volvopluteus*, which lack a universal veil and have a pinkish spore deposit. One PERTH collection of *Volvopluteus gloiocephalus* had been originally identified as *Volvariella bombycina*, a large, lignicolous species predominant in the northern hemisphere and unconfirmed in Australia. It is unlikely to occur in WA unless introduced.

Some morphological variation is evident among the Western Australian collections of *Volvopluteus earlei*. For example, the mean spore size of the southern collections (e.g. 13.5 × 8.4 µm for PERTH 07680287) is greater than that of a northern collection (PERTH 09519432: 11.8 × 7.5 µm). Also, among and within the Western Australian collections of *V. earlei* the hymenial cystidia vary in shape and in the presence and length of an apical extension. These features, and the presence and abundance of pleurocystidia, were observed in some cases to be highly variable among and within individual specimens. Similar variability in spores and cystidia has been reported for *V. earlei* outside Australia. For example, mean spore size has been quoted as 13.53 × 8.38 µm for Italian collections (Giannoni *et al.* 2018), and 12.5 x 7 µm for Japanese collections (Kasuya *et al*. 2018). Collections lacking any pleurocystidia have been reported from Spain (Justo & Castro 2010), and some from Italy have non-rostrate cheilocystidia or lack hymenial cystidia (e.g. *V. earlei* f. *acystidiatus* (N.C. Pathak) Vizzini & Contu: Justo *et al.* 2011b).

Volvolpluteus earlei had not been previously recorded in Australia; however, it has been documented from many other parts of the world (see Justo & Castro 2010) including humid areas such as the Congo, Cuba, Mexico, and southern USA, and parts of Mediterranean Europe such as Italy and Spain. It is also known from some temperate areas such as Japan (Kasuya *et al*. 2018). Its widespread occurrence predominantly in the northern hemisphere and lack of previous records in Australia suggest that it may have been introduced recently into southern WA from elsewhere. In the Perth region it is only currently known from two, artificially-watered, grassed urban parks. Its basidiomata are often quite conspicuous at these sites and appear to emerge after an episode of warm, humid weather early in the year (February, March), much earlier than the main, local fungal fruiting season (usually June–August). The status of tropical Australian specimens of *V. earlei* is less certain. The collection from near Broome in WA was found in a pile of dirt and mulch used for landscaping. Similarly, a collection from near Katherine in the Northern Territory (DNA D0290038, see Figure 1) was fruiting on a mix of dirt and native grasses from a grader spill beside a highway. Both are anthropogenically disturbed sites, and spores could have been introduced to the sites. An additional, un-vouchered observation (M. Barrett, Dec. 1995) in grader spill near the northern edge of Beverley Springs Station (now Charnley River Station), in a very remote area of the Kimberley Region, was very unlikely to have been transported to the site, although the habitat was certainly disturbed. Introduction of genotypes with horticulture is likely, but *V. earlei* may also have been indigenous in Northern Australia prior to European arrival. Either way, the species evidently is encouraged by anthropogenic disturbance. Even though there have been few records of it to date, *V. earlei* may be widespread or at least becoming widespread in Australia. The first regional records of *V. earlei* also have been made in recent years in some other parts of the world. Justo and Castro (2010) reported on the first record in Spain and suggested that it may be a tropical species alien to Europe. Spanish and Italian collections of *V. earlei* were collected during late spring and summer in artificially irrigated gardens.

PERTH 07552440 is the first record of *Volvariella taylorii* in WA. Another record, recently listed by Bougher and Barrett (2020) as '*Volvopluteus* sp. (small fruit bodies with non-viscid grey pileus)' from sandy soil at Bold Park, Perth may also be *V. taylorii* but its identity cannot be confirmed as no specimen was vouchered (photographs show a small grey pileus and grey volva). Leonard (2015) in referring to a Queensland record of *V. taylorii* (as *V. pusilla* var. *taylori*) wrote: 'there are references in the Australian literature but do not appear to be any collections in Australian Herbaria'; however, there is at least one preserved Australian collection identified as *V. taylorii*, originating from Blackbutt, Queensland in 1989 (BRI AQ0646466). Based on the limited records so far, it seems that *V. taylorii* may be expected to occur over wide parts of Australia but perhaps it has been sparsely reported because it is small and/or it may fruit less frequently or abundantly than some other pink-spored, volvate fungi such as *Volvopluteus gloiocephalus*.

Four species of pink-spored, volvate fungi are currently known to occur in WA (Table 3) although there are likely to be others. For example, in northern WA, at least three unidentified *Volvariella* species are known (M.D. Barrett, unpublished data). A census of the larger fungi of WA (Hilton 1982) includes three species of *Volvariella*: *V. bombycina*, *V. speciosa* and *V. cycnopotamia* (Berk.) Singer. The inclusion of *V. bombycina* cannot be assessed because the associated voucher (UWA 1219) cannot be located. The census cites UWA 1566, 1065 and 819 as collections of *V. speciosa* (stating that specimens so far collected intergrade with *V. speciosa* var. *gloiocephala* (DC.) Singer). Two of these vouchers (UWA 1566, PERTH 00761427; UWA 819, PERTH 00750425) represent *Volvopluteus gloiocephalus*; the third (UWA 1065) cannot be located. *Volvariella cycnopotamia* was described by Berkeley (1881: 389, as *Agaricus cycnopotamia* Berk.) who examined scanty materials of a single collection from 'Swan River' sent to him at The Royal Botanic Gardens, Kew in 1849 by James Drummond. That collection has pink, subglobose spores 5.5–8 × 4.7–6.5 µm (Pegler 1965). No subsequent collections attributable to this species have been reported from WA, but there is one from Queensland in 2010 (BRI AQ0793965). The epithet is more accurately spelt *V. cygnopotamia*, as its etymology is presumably based on 'Swan River'.

Table 3. Some comparative distinguishing features of the four species of pink-spored, volvate agaricoid fungi currently known to occur in Western Australia.

Character	***Volvopluteus gloiocephalus***	***Volvopluteus earlei***	***Volvariella taylorii***	***Volvariella cygnopotamia***
Pileus width	mostly > 50 mm	< 50 mm	< 50 mm	< 50 mm
Pileus surface	viscid, slowly dry	viscid, rapidly dry	dry	dry
Volva	white	white	grey	white? *
Spores	> 10 µm; ellipsoid	> 10 µm; ellipsoid	< 10 µm; ellipsoid-ovoid-oblong	< 10 µm; subglobose
Pileipellis	gelatinised ixocutis	gelatinised ixocutis	non-gelatinised cutis	non-gelatinised cutis
WA distribution	southern	southern & northern	southern	southern
WA frequency & habitat	common: gardens, woodchips, mulch, lawns	uncommon: grass, garden woodchip heap	uncommon: one location to date - soil	rare: ground

*The protologue for *Volvariella cygnopotamia* by Berkeley (1881, as '*Agaricus cycnopotamia*') quotes the following: 'Volva composed of intricate threads, with a central dark patch which appears to contain spiral vessels, but the material is so scanty that it is impossible to speak with certainty.'

Acknowledgements

Curators at the Western Australian and Northern Territory herbaria are thanked for their support accessing and processing specimens used in this study. Graham Brown and David Liddle, and Kings Park Science are thanked for logistical and material support during collection expeditions during which the tropical specimens were obtained. We thank Hana Ševčíková (referee) for her constructive comments on this paper.

References

Berkeley, M.J. (1881). Australian Fungi.— II. Received principally from Baron F. von Mueller. *Journal of the Linnean Society, Botany* 18: 383–389.

Bougher, N.L. & Barrett, M.D. (2020). Fungi and slime moulds recorded in surveys at Kings Park and Bold Park - urban bushlands Perth, Western Australia. *The Western Australian Naturalist* 31: 191–251.

Bougher, N.L. & Syme, K. (1998). *Fungi of Southern Australia*. (University of Western Australia Press: Nedlands.)

Darriba D., Taboada, G.L., Doallo, R. & Posada, D. (2012). jModelTest 2: more models, new heuristics and parallel computing. *Nature Methods* 9: 772.

Ghobad-Nejhad, M., Langer, E., Antonín, V., Gates, G., Noroozi, J. & Zare, R. (2020). The gilled fungi and boletes of Iran: diversity, systematics, and nrDNA data. *Mycologia Iranica* 7: 1–43.

Giannoni, F., Pera, U. & Maggiora, M.D. (2018). *Volvopluteus earlei*, an uncommon species throughout Europe, new for Tuscany. *Micologia Toscana* 0: 11–25.

Hilton, R.N. (1982). A census of the larger fungi of Western Australia. *Journal of the Royal Society of Western Australia* 65: 1–15.

Holec, J., Kunca, V., Ševčíková, H., Dima, B., Kříž, M. & Kučera, T. (2018). *Pluteus fenzlii* (Agaricales, Pluteaceae) – taxonomy, ecology and distribution of a rare and iconic species. *Sydowia* 70: 11–26.

Justo, A. & Castro, M.L. (2010). The genus *Volvariella* in Spain: *V. dunensis* comb. & stat. nov. and observations on *V. earlei*. *Mycotaxon* 112: 261–270.

Justo, A., Minnis, A.M., Ghignone, S., Menolli, N. Jr., Capelari, M., Rodrıguez, O., Malysheva, E., Contu, M. & Vizzini, A. (2011a). Species recognition in *Pluteus* and *Volvopluteus* (Pluteaceae, Agaricales): morphology, geography and phylogeny. *Mycological Progress* 10: 453–479.

Justo, A., Vizzini, A., Minnis, A.M., Menolli Jr. N., Capelari, M., Rodríguez, O., Malysheva, E., Contu, M., Ghignone, S. & Hibbett D.S. (2011b). Phylogeny of the Pluteaceae (Agaricales, Basidiomycota): taxonomy and character evolution. *Fungal Biology* 115: 1–20.

Khan, J., Sher, H., Izhar, A., Haqnawaz, M. & Khalid, A.N. (2022). *Pluteus variabilicolor* and *Volvopluteus earlei*, new records for Pakistan. *Mycotaxon* 137: 109–121. https://doi.org/10.5248/137.109.

Kalichman, J., Kirk, P.M. & Matheny, P.B. (2020). A compendium of generic names of agarics and Agaricales. *Taxon* 69: 425–447. https://doi.org/10.1002/tax.12240.

Kasuya, T., Maruyama, T., Ikeda, Y., Fuse, K. & Hosaka, K. (2018). *Volvopluteus earlei* Agaricales, Pluteaceae, new to Japan. *Japanese Journal of Mycology* 59: 47–52.

Kaygusuz, O., Türkeful, I., Knudsen, H. & Menolli Jr., N. (2021). *Volvopluteus* and *Pluteus* section *Pluteus* (Agaricales: Pluteaceae) in Turkey based on morphological and molecular data. *Turkish Journal of Botany* 45: 224–242.

Kearse, M., Moir, R., Wilson, A., Stones-Havas, S., Cheung, M., Sturrock, S., Buxton, S., Cooper, A., Markowitz, S., Duran, C., Thierer, T., Ashton, B., Meintjes, P. & Drummond, A. (2012). Geneious basic: an integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics* 28: 1647–1649.

Kornerup, A. & Wanscher, J.H. (1978). *Methuen handbook of colour*. (Methuen: London.)

Krom, I.Y., Ageev, D.V., Bulyonkova, T.M. & Morovoza, O.V. (2019). New to Russia and little-known species of agaricoid fungi from South Krasnoyarsk Territory (Mikrozakaznik Zharovsky, Russia). *Turczaninowia* 22: 119–127.

Leonard, P. (2015). *Volvariella pusilla* var. *taylori*. Queensland Fungal Record Copyright Queensland Mycological Society. https://qldfungi.org.au/wpcontent/uploads/2014/06/Volvariella-pusilla-var-taylori.pdf [accessed 7 November 2022].

Matheny, P.B., Curtis, J.M., Hofstetter, V., Aime, M.C., Moncalvo, J.M., Ge, Z.W., Yang, Z.L., Slot, J.C., Ammirati, J.F., Baroni, T.J., Bougher, N.L., Hughes, K.W., Lodge, D.J., Kerrigan, R.W., Seidl, M.T., Aanen, D.K., DeNitis, M., Daniele, G.M., Desjardin, D.E., Kropp, B.K., Norvell, L.L., Parker, A., Vellinga, E.C., Vilgalys, R. & Hibbett, D.S. (2006). Major clades of Agaricales: a multilocus phylogenetic overview. *Mycologia* 98: 982–995.

Pegler, D.N. (1965). Studies on Australasian Agaricales. *Australian Journal of Botany* 13: 323–356.

Pradeep, C.K., Vrinda, K.B., Mathew, S. & Abraham, T.K. (1998). The genus *Volvariella* in Kerala state, India. *Mushroom Research* 7: 53–62.

Rao G., Dai D., Zhang, B. & Li, Y. (2021). A new record species of *Volvopluteus* from China. *Microbiology China* 48: 3791–3798.

Seok, S.-J., Kim, Y.-S., Weon, H.-Y., Lee, K.-H., Park, K.-M., Min, K.-H. & Yoo, K.-H. (2022). Taxonomic Study on *Volvariella* in Korea. *Mycobiology* 30: 183–192.

Ševčíková, H., Borovička, J. & Gates, G. (2021). *Pluteus hubregtseorum* (Pluteaceae), a new species from Australia and New Zealand. *Phytotaxa* 496: 147–158.

Stamatakis, A. (2014). RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30: 1312–1313. https://dx.doi.org/10.1093/bioinformatics/btu033

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dbca.wa.gov.au/nuytsia/ *Nuytsia* 34: 203–219
https://doi.org/10.58828/nuy01059 Published online 26 October 2023

Marasmius australotrichotus (Marasmiaceae), a new setose species from Australia, and an intriguing range extension for *M. paratrichotus*

Frances E. Guard[1], John Dearnaley[2], Teresa Lebel[3,4], Matt D. Barrett[5] and Neale L. Bougher[6]

[1] University of Southern Queensland, Toowoomba, Queensland 4350
[2]School of Agriculture & Environmental Science, Faculty of Health,
Engineering & Sciences, University of Southern Queensland, Toowoomba, Queensland 4350
[3]State Herbarium of South Australia, Hackney Road, Adelaide, South Australia 5000
[4]Royal Botanic Gardens Victoria, Private Bag 2000, Victoria 3141
[5]Australian Tropical Herbarium, James Cook University,
PO Box 6811, Cairns, Queensland 4870
[6]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[1]Corresponding author, email: franguard@icloud.com

Abstract

Guard, F.E., Dearnaley, J., Lebel, T., Barrett, M.D. & Bougher, N.L. *Marasmius australotrichotus* (Marasmiaceae), a new setose species from Australia, and an intriguing range extension for *M. paratrichotus*. *Nuytsia* 34: 203–219 (2023). Based on morphological characters and molecular analysis of the nrITS regions, *Marasmius australotrichotus* F.E.Guard, J.Dearnaley & T.Lebel, the first known Australian species in sect. *Sicci*, ser. *Spinulosi* is described. The distribution of *M. paratrichotus* is extended from the West African island nation of São Tomé and Príncipe (ST&P) to Christmas Island (CI) and northern Western Australia (WA). Classification, distinguishing characters, habitat variability, geographic distribution and possible dispersal mechanisms are discussed.

Introduction

Marasmius Fr. is a widespread genus of basidiomycete fungi, particularly well-represented in the tropics and subtropics. *Marasmius* species are usually saprotrophs, and most are small to medium-sized fungi (1–20 mm pileus diameter), decomposing twigs and leaf litter in rainforest, wet sclerophyll forest, and disturbed habitats including road verges, gardens and lawns. Traditionally, *Marasmius* was divided into sections and subsections by morphological features (Singer 1986; Antonin & Noordeloos 2010). Antonin and Noordeloos recognised four sections: *Marasmius, Hygrometrici, Globulares* and *Sicci* (including series *Atrorubentes*, *Haematocephali*, *Leonini* and *Spinulosi*) in *Marasmius sensu stricto*. Their work was based on morphology alone, and while recognising that phylogenetic data would be required to clarify the genus, they preserved the older concepts. Section *Sicci* Singer, subsect. *Siccini* Singer, ser. *Spinulosi* was erected to accommodate *Marasmius* species with non-insititious stipes, dextrinoid hyphae, and pileal, stipe and/or hymenial setae (Clémençon 1982). The presence of setae was the distinguishing feature of this series. Section *Sicci* Singer, subsect. *Siccini* Singer, ser. *Atrorubentes* (Desjardin & Horak 1997) was erected to correct some confusion caused by Singer misnaming the series *Actinopus*, and to include species without pileal or hymenial setae,

© Department of Biodiversity, Conservation and Attractions 2023 ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

but with pruinose stipes produced by irregular, cylindrical, cystidioid or setoid cells, and absence of *Siccus*-type broom cells from the stipe.

The type species of ser. *Spinulosi*, *M. cohaerens* (Pers.) Cooke & Quél., was originally collected from Germany, and it is now considered to occur across Europe and North America (Antonin & Noordeloos 2010). Other species in ser. *Spinulosi* sensu Singer have been reported from Africa (Shay *et al.* 2017; Grace *et al.* 2019), south-east Asia (Tan *et al.* 2009; Wannathes *et al.* 2009), Korea (Antonín *et al.* 2012), Far-eastern Russia (Kiyashko *et al.* 2014) and Argentina (Niveiro *et al.* 2018). These vary in the presence of pleurocystidia, being present in many but absent in others, e.g., the 'trichotus' group. Some taxa have smooth cells (*Globulares*-type) in the pileipellis, while others have *Siccus*-type broom cells. Caulocystidia are variable and within closely related taxa may include *Siccus*-type broom cells, transitional cells with narrow body and sparse elongated stellate branches, irregular, cylindrical blunt cells, intermixed with long, lanceolate, thick-walled setae (Figure 1). The morphological distinction between ser. *Spinulosi* with setoid caulocystidia and ser. *Atrorubentes* with obtuse caulocystidia was not always clear as transitional forms have been shown to occur (Desjardin & Horak 1997; Antonin 2007).

Tan *et al.* (2009), Wannathes *et al.* (2009), Shay *et al.* (2017) and Grace *et al.* (2019) have produced a large body of molecular data based on nrITS gene region for *Marasmius* sensu stricto. Their findings confirmed that while nrITS is very useful for delimiting species and confirming closely related morphogroups, it does not support the morphology-based infrageneric classification. None of the series in the traditional concept of sections *Globulares* and *Sicci* are monophyletic in these studies. However, a recent study by Oliveira *et al.* (2020), which focussed on sect. *Globulares* (*Globulares-Sicci* complex), based on a larger global dataset, using both nrITS and the more conserved marker, LSU, showed that historical 'ser. *Spinulosi*' species appeared in at least three unrelated clades, grouping with *M. cohaerens*, *M. purpureostriatus* and *M. atrorubens*. That study demonstrated the existence of several monophyletic supra-specific groups, equating to Singer's 'stirpes', a classification level below series for grouping morphologically similar species (Singer 1976). Oliveira *et al.* (2020) raised subsection *Spinulosi* J.S.Oliveira & Moncalvo, with type species *M. cohaerens* within series *Cohaerentes* J.S.Oliveira & Moncalvo, and placed series *Atrorubentes* Desjardin & E.Horak emend. J.S.Oliveira & Moncalvo in subsection *incertae sedis*. In their study, series *Atrorubentes* included *M. trichotus* Corner.

Marasmius trichotus, described from Singapore (Corner 1996), is a distinctive SE Asian species, with currently known distribution from India to Papua New Guinea with a habitat preference for tropical rainforest. Its morphological characters include conspicuous golden setae on the pileus and golden to rusty-brown setae on the stipe (Corner 1996; Desjardin & Horak 1997; Wannathes *et al*. 2009). More recently, Grace *et al*. (2019) described *M. paratrichotus* C.L.Grace, Desjardin & B.A.Perry from a single collection in the West African island nation of São Tomé and Príncipe (ST&P). It is similar to *M. trichotus*, but with a dull, velvety pileus and pubescent stipe.

Extensive sampling of *Marasmius* species in north-eastern Australia in 2001, 2018 and 2021, combined with unique opportunities to collect fungi in the remote Kimberley region of Western Australia and Christmas Island, revealed several collections which had distinct setae on the pileus and stipe. While morphologically similar to *M. trichotus*, our analyses show that some of the collections represent a new taxon, *M. australotrichotus sp. nov.*, which we describe here, while two are an intriguing range extension for *M. paratrichotus*.

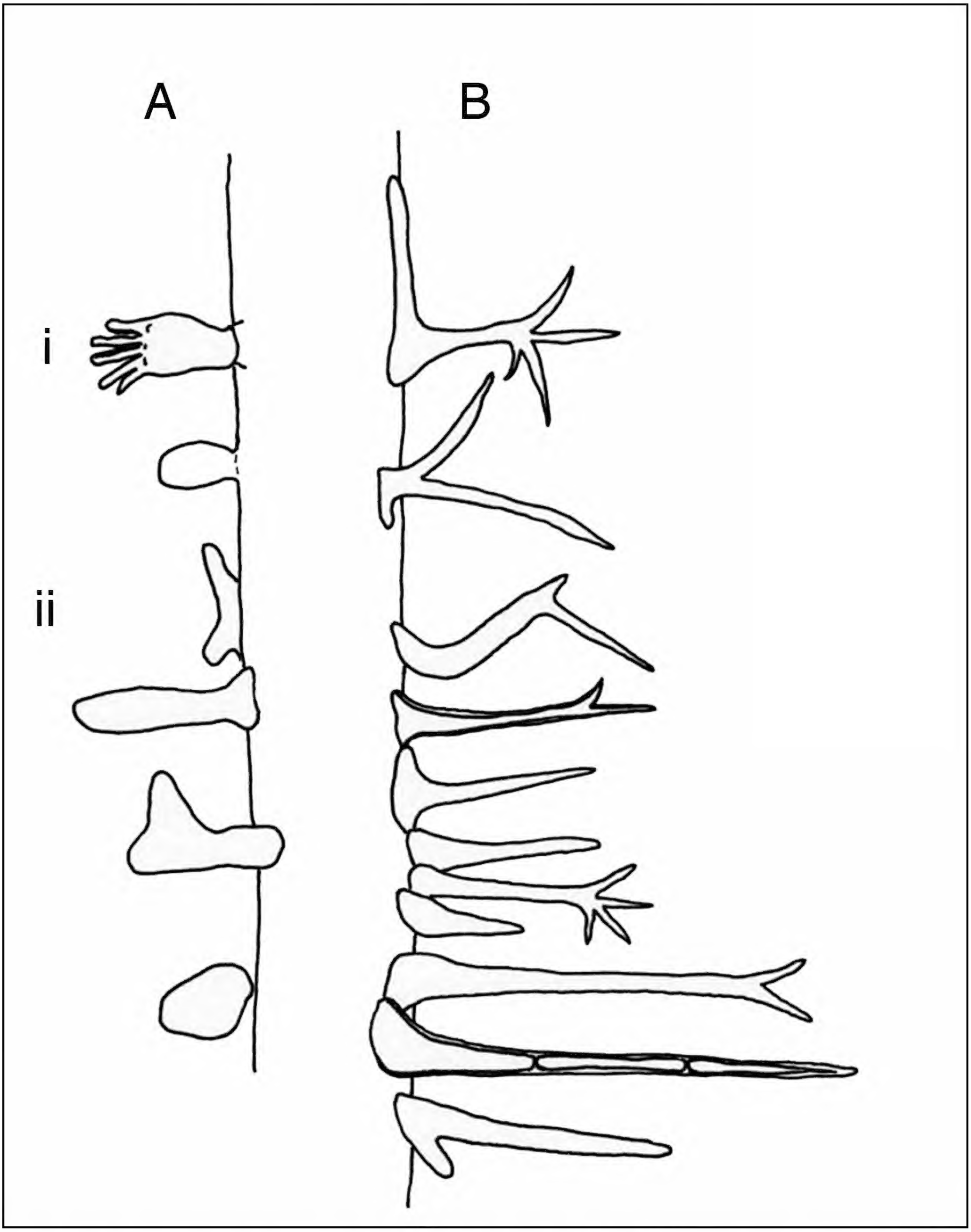

Figure 1. Variability of stipe cystidia within *Marasmius australotrichotus* and *M. paratrichotus* and usage of terms '*caulocystidia*' and '*caulosetae*'. A. *Caulocystidia* – i. *Siccus*-type broom cells with terminal digitate projections and ii. irregular shaped cystidia with obtuse apices. B. *Caulosetae* – lanceolate, bifurcate, branched, stellate cystidia with acute apices. In this study all cells with long pointed apices are termed *caulosetae*.

Materials and methods

Sampling protocols

Collections of *M. australotrichotus* were made in far north Queensland (2018, 2021 and 2022) under Queensland Department of Environment and Science Permits No. WITK18734918-1 to 2021 and P-PTUKI-100021825-1 to 2023. One collection of *M. paratrichotus* was made by M.D. Barrett at Theda Station, north Kimberley, WA, under Western Australian Scientific Purposes license SW008226 in 2003 and the other by N.L. Bougher and K. Ruthrof on Christmas Island in 2016. Field work on Christmas Island was carried out under Commonwealth areas Permit AU-COM2015-295 and Christmas Island National Park Permit CINP_2015_16_3.

These collections were supplemented with herbarium material from the Queensland Herbarium (BRI) and the National Herbarium of Victoria (MEL) including further specimens of *M. australotrichotus* from far north Queensland and south-east Queensland, as well as one from the Northern Territory. The Australian specimens of *M. paratrichotus* are held in the Western Australian Herbarium (PERTH).

Morphological protocols

Fresh collections were photographed, described and a sample placed in silica gel prior to DNA analysis. The basidiomes were then dried using an *Ezidri* Snackmaker FD500 (Hydraflow Industries Ltd, Upper Hutt, NZ) food dehydrator at the lowest setting for at least 12 hours. Spore prints were made where possible. Macroscopic features including details of pileus, lamellae, stipe, substrate and habit were recorded from the fresh material. Colours were recorded according to the Flora of British Fungi Colour Identification Chart (Royal Botanic Gardens 1969).

Microscopic characters of hand-sectioned dried material were examined using a Prism Optical (Model EX-30T) compound microscope with Tucsen GT12 camera (Tucsen Photonics Co., China) with a 100× objective. Sections were rehydrated and examined in Congo Red in water, in 5% potassium hydroxide (KOH) or Melzer's Reagent. Microscopic details were recorded with Mosaic V2.0 software (http://www.tucsen.com). For spore measurement, the abbreviation Q refers to the length/width ratio, Q_m the mean of Q values. Values in square brackets are standard deviation [SD] for mean measurements of length and width and Q_m values. Caulocystidia include *Siccus*-type broom cells and irregular, smooth, terminally obtuse, cylindrical cells. Lanceolate, solitary, branched or stellate cells with acute apices are termed caulosetae in this paper, and transitional forms are also termed caulosetae, if they have acute apices (Figure 1).

Molecular protocols

Samples from each collection were ground with 2 lead pellets in a bead mill (Fast Prep-24^{TM} 5G, MP Biomedicals, Ca., USA). Genomic DNA was extracted using the E.Z.N.A. Forensic DNA Extraction Kit (Omega Bio-tek Inc., Norcross, GA), following the standard protocol for hair, nails and feathers, apart from substituting 0.8 µL β mercapto-ethanol for 20 µL 1M DTT and using 50 µL elution buffer instead of 100 µL for a more concentrated extract. The nuclear ribosomal internal transcribed spacer region (ITS1+5.8S+ITS2) was amplified using primers ITS1F (Gardes & Bruns 1993) and ITS4 (White *et al.* 1990) in a polymerase chain reaction (PCR) mixture of 1 µL (10 pmol/ µL) of each primer, 12.5 µL My Taq Red Mix, 0.8 µL of 10% bovine serum albumin (BSA), 7.7 µL sterile water and 2 µL DNA extract. The nuclear ribosomal large subunit (nrLSU) gene region was amplified using LR7 and

LROR primers (Vilgalys & Hester 1990) in a PCR mixture of 1 µL (10 pmol/ µL) of each primer, 12.5 µL My Taq Red Mix, 0.8 µL 10% BSA, 7.7 µL sterile water and 2 µL DNA extract. The PCR thermal cycling conditions included 35 cycles of 95°C for 1 minute, 51°C for 1 minute and 72°C for 1 minute, with a final extension step of 72°C for 10 minutes for the ITS, and 95°C for 1 minute, 48°C for 1 minute, 72°C for 1 minute, with a final extension step of 72°C for 10 minutes for LSU. Successful PCR amplification was checked by gel electrophoresis. PCR products were sent to Macrogen, Seoul, for Sanger sequencing using the original amplification primers.

Sequence editing was done within Geneious Prime 2022.1.1. (https://www.geneious.com) and initial alignment was performed using MAFFT (Katoh & Standley 2013). Sequences were trimmed, then edited manually. A BLAST search against the National Centre for Biotechnology Information (NCBI) database (http://www.ncbi.nlm.nih.gov/) was used to determine closest sequence matches. The final alignment included sequences from taxa in ser. *Spinulosi* sensu Singer and ser. *Atrorubentes* as proposed by Oliveira *et al.* (2020). Newly generated sequences (in **bold**) used in the construction of the phylogenetic tree are shown in Table 1.

Maximum likelihood phylogenetic analysis was conducted using RAxML 8.2.11 (Stamatakis 2014) with the GTRGAMMA model using default parameters and 1,500 rapid bootstrap (BS) replicates. Bayesian analysis was performed with Mr Bayes 3.2.6 (Huelsenbeck 2001) using the substitution model GTR and Metropolis Coupled (MCMC) settings, for 50,000 iterations. New sequences were registered with GenBank.

Results

The nrITS phylogeny of the *Marasmius* taxa sampled for this study is shown in Figure 2. The eight samples of the putative new species *M. australotrichotus* formed a monophyletic clade, with ML bootstrap support of 97% and posterior probability (PP) of 1.0. All sequences of *M. australotrichotus* were 98.94–99.55% identical with each other. The sister species to *M. australotrichotus* was resolved as *M. neotrichotus* Niveiro, N.A.Ramírez & Antonin from Argentina (Niveiro *et al.* 2018) with low to moderate support (56% BS, 0.97 PP). The two new specimens of *Marasmius paratrichotus* were resolved as a clade with the type specimen from São Tomé, with ML bootstrap support (BS) of 97% and posterior probability (PP) of 0.95. The sequences of *M. paratrichotus* were 99.77–99.96% identical with each other. *M. paratrichotus* had a close sister relationship to *M.* aff. *trichotus* from India (73% BS, 0.94 PP), and also *M. trichotus* from Thailand, (97% BS, 1.0 PP for the combined clades). The type species for ser. *Spinulosi*, *M. cohaerens* belonged to a clade distant to the taxa of this study (Figure 2).

Table 1. Dataset of 53 *Marasmius* species used in the phylogenetic analysis for this study. New sequences in **bold.**

Species	Sect./Series Traditional classification	Collection #	GenBank # ITS/LSU
M. atrorubens	*Sicci/Atrorubentes*	JO528	KP635207
M. atrorubens	*Sicci/Atrorubentes*	JO489	KP635206
M. australotrichotus	***Sicci/Spinulosi***	**AMW1F**	**OQ725921**
M. australotrichotus	***Sicci/Spinulosi***	**PIF26879**	**OQ725926**
M. australotrichotus	***Sicci/Spinulosi***	**GMB-2014**	**KP012696**
M. australotrichotus	***Sicci/Spinulosi***	**SMF 3296**	**OQ725923/OQ725916**
M. australotrichotus	***Sicci/Spinulosi***	**PIF27894**	**OQ725925/OQ725917**

Species	Sect./Series Traditional classification	Collection #	GenBank # ITS/LSU
M. australotrichotus	***Sicci/.Spinulosi***	**F2021072**	**OQ725920/OQ725914**
M .australotrichotus	***Sicci/Spinulosi***	**Cribb-249**	**OQ725927**
M. australotrichotus	***Sicci/Spinulosi***	**MDB F2022110**	**OQ725924**
M. chrysoblepharioides	*Sicci/Spinulosi*	SI-15-24	MF683956
M. cohaerens	*Sicci/Spinulosi*	TENN 067870	KF774179
M. cohaerens	*Sicci/Spinulosi*	TENN 067916	KF774178
M. cohaerens	*Sicci/Spinulosi*	BRNM 695761	GU266260
M. cohaerens	*Sicci/Spinulosi*	LE295982	KF774174
M. cohaerens var. mandshuricus	*Sicci/Spinulosi*	LE295986	KF774171
M. cohaerens var. lachnophyllus	*Sicci/Spinulosi*	iNAT:16190382	MZ197975
M. corrugatiformis	*Sicci/Atrorubentes*	Buyck 97.425	KX148981
M. dendrosetosus	*Sicci/Spinulosi*	JES 205	NR158833
M. dendrosetosus	*Sicci/Spinulosi*	JES 211	KX148996
M. elegans	*Sicci/ Atrorubentes*	JAC13253	OQ282799
M. elegans	*Sicci/ Atrorubentes*	JAC10928	OQ282785
M. grandisetulosus	*Sicci/Spinulosi*	DED 8225	KX953743
M. grandisetulosus	*Sicci/Spinulosi*	DED 8257	KX953744
M. grandiviridis	*Globulares*	NW152	EU643514
M. hinnuleus	*Sicci/Haematocephali*	JES 217	KX148988
M. hypophaeus	*Sicci/Haematocephali*	NW285	EU935484
M. iras	*Sicci/Atrorubentes*	NW276	EU935486
M. iras	*Sicci/Atrorubentes*	NW375	EU935487
M. katangensis	*Sicci/Atrorubentes*	JES 227	KX148991
M. laticlavatus	*Globulares*	NW412	EU643511
M. longisetosus	*Sicci/Spinulosi*	JO248	JX424040
M. longisetosus	*Sicci/Spinulosi*	SP 417470	NR154160
M. megistus	*Sicci/Leonini*	JES 163	KX148992
M. neotrichotus	*Sicci/Spinulosi*	SI-7-13	MF683958
M. nummularius	*Sicci/Spinulosi*	NW396	EU935493
M. nummularius	*Sicci/Spinulosi*	JES121	KX148979
M. ochroleucus	*Sicci/Atrorubentes*	LE 295978	KF912952

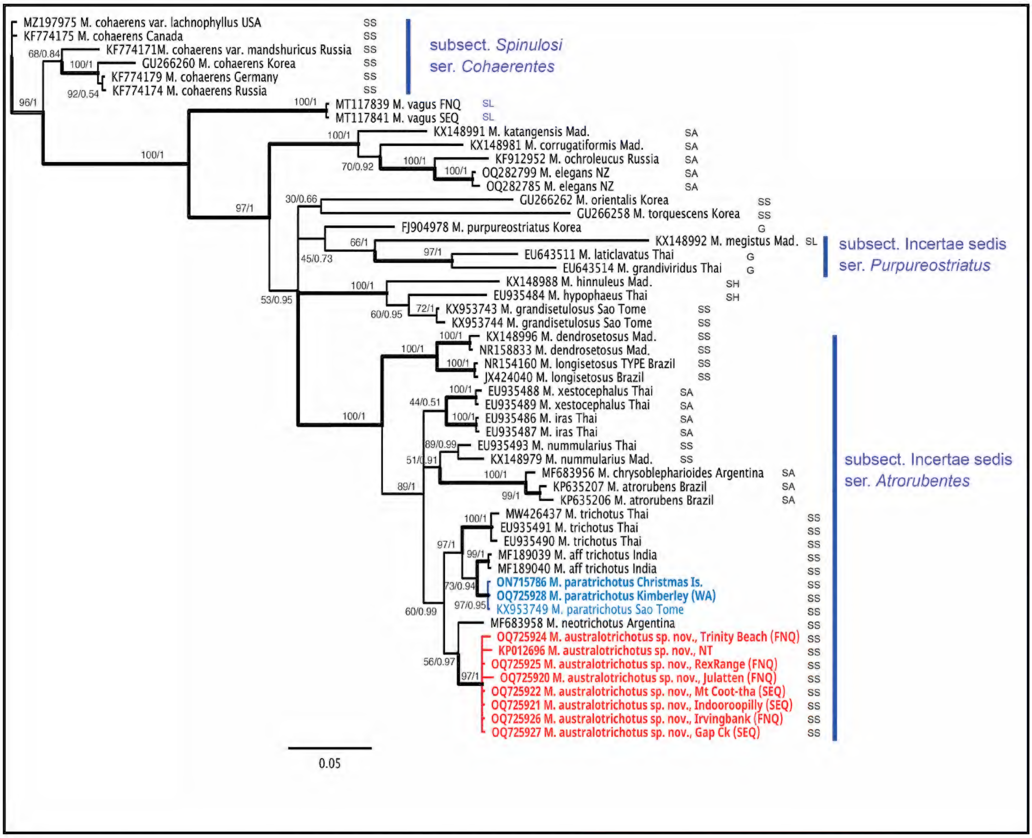
MZ197975 M. cohaerens var. lachnophyllus USA SS
KF774175 M. cohaerens Canada SS
68/0.84
KF774171M. cohaerens var. mandshuricus Russia SS
100/1
GU266260 M. cohaerens Korea SS
KF774179 M. cohaerens Germany SS
92/0.54
KF774174 M. cohaerens Russia SS
subsect. Spinulosi
ser. Cohaerentes
96/1
100/1
MT117839 M. vagus FNQ SL
MT117841 M. vagus SEQ SL
100/1
100/1
KX148991 M. katangensis Mad. SA
KX148981 M. corrugatiformis Mad. SA
100/1
KF912952 M. ochroleucus Russia SA
70/0.92
100/1
OQ282799 M. elegans NZ SA
OQ282785 M. elegans NZ SA
97/1
30/0.66
GU266262 M. orientalis Korea SS
GU266258 M. torquescens Korea SS
FJ904978 M. purpureostriatus Korea G
66/1
KX148992 M. megistus Mad. SL
45/0.73
97/1
EU643511 M. laticlavatus Thai G
EU643514 M. grandiviridus Thai G
subsect. Incertae sedis
ser. Purpureostriatus
100/1
KX148988 M. hinnuleus Mad. SH
53/0.95
EU935484 M. hypophaeus Thai SH
60/0.95
72/1
KX953743 M. grandisetulosus Sao Tome SS
KX953744 M. grandisetulosus Sao Tome SS
100/1
KX148996 M. dendrosetosus Mad. SS
100/1
NR158833 M. dendrosetosus Mad. SS
100/1
NR154160 M. longisetosus TYPE Brazil SS
JX424040 M. longisetosus Brazil SS
100/1
EU935488 M. xestocephalus Thai SA
44/0.51
EU935489 M. xestocephalus Thai SA
100/1
100/1
EU935486 M. iras Thai SA
EU935487 M. iras Thai SA
89/0.99
EU935493 M. nummularius Thai SS
51/0.91
KX148979 M. nummularius Mad. SS
100/1
MF683956 M. chrysoblepharioides Argentina SA
89/1
KP635207 M. atrorubens Brazil SA
99/1
KP635206 M. atrorubens Brazil SA
subsect. Incertae sedis
ser. Atrorubentes
100/1
MW426437 M. trichotus Thai SS
EU935491 M. trichotus Thai SS
97/1
EU935490 M. trichotus Thai SS
99/1
MF189039 M. aff trichotus India SS
MF189040 M. aff trichotus India SS
73/0.94
ON715786 M. paratrichotus Christmas Is. SS
OQ725928 M. paratrichotus Kimberley (WA) SS
97/0.95
KX953749 M. paratrichotus Sao Tome SS
60/0.99
MF683958 M. neotrichotus Argentina SS
OQ725924 M. australotrichotus sp. nov., Trinity Beach (FNQ) SS
KP012696 M. australotrichotus sp. nov., NT SS
56/0.97
OQ725925 M. australotrichotus sp. nov., RexRange (FNQ) SS
97/1
OQ725920 M. australotrichotus sp. nov., Julatten (FNQ) SS
OQ725922 M. australotrichotus sp. nov., Mt Coot-tha (SEQ) SS
OQ725921 M. australotrichotus sp. nov., Indooroopilly (SEQ) SS
OQ725926 M. australotrichotus sp. nov., Irvingbank (FNQ) SS
OQ725927 M. australotrichotus sp. nov., Gap Ck (SEQ) SS
0.05

Figure 2. Phylogenetic analysis for *Marasmius australotrichotus* and *M. paratrichotus* inferred from a Bayesian analysis of the nrITS region (ITS1, 5.8S rDNA and ITS2). ML bootstrap proportions and Bayesian posterior probabilities are shown as BS/PP respectively. Nodes receiving support values greater than 95/0.95 are represented by **bold** branches. *Marasmius* sequences indicated in red type are *M. australotrichotus sp. nov.* from this study, and in blue type *M. paratrichotus*, including the holotype KX935749 from São Tomé. New sequences are in bold. The traditional classification is included as follows: SA = Subsect. *Siccini*, ser. *Atrorubentes*, SH = ser. *Haematocephali*, SL = ser. *Leonini*, SS = ser. *Spinulosi*, G = *Globulares*. The new classification as proposed by Oliveira is added where possible.

Taxonomy

Marasmius australotrichotus F.E.Guard, Dearnaley & T.Lebel, *sp. nov.*

Type: Queensland, Trinity Beach, S 16° 47’ 52”, E 145° 41’ 09”, 31 December 2022, *M.D. Barrett* MDB F2022110 (*holo*: BRI AQ1039752). [MB 848444].

Pileus 5–15 mm diam., apricot (47) to rust (13) becoming orange-yellow with rusty tawny (14) centre, convex, campanulate, almost applanate, occasionally umbonate, smooth with wavy margin, surface finely velutinous, dry, *flesh* very thin (<1 mm), off-white. *Lamellae* free to adnexed, sub-close, 14–16, with 3–4 tiers of lamellulae, cream (4D) to buff (52), non-marginate. *Stipe* 25–60 (–80) × 0.5–1 mm, central, reddish-brown strigose base, pale brown mid-section and cream apex, hollow, cartilaginous, surface may appear smooth but under a hand lens is finely hispid with brownish hairs. (Figure 3)

Basidiospores 10.5–13 × 3.5–4.5 µm, mean 11.9 [± 0.69 SD] × 3.9 [± 0.33 SD] µm, Q = 2.49–3.71, Q_m = 3.08 [± 0.29 SD], (n = 50 spores from 4 specimens), narrow ellipsoid in face view, often flattened adaxially and slightly curved in profile, smooth, hyaline, thin-walled, inamyloid. *Basidia* three to four-spored, rare, 21–23 × 6–7.5 µm. *Basidioles* 20–24 × 5–7 µm, fusiform, occasionally clavate. *Cheilocystidia Siccus*-type broom cells, often forming a sterile edge, cylindrical, clavate, occasionally branched, main body, 10–19 × 5–9 µm, with multiple apical setulae, 2.5–6.5 × 1–1.5 µm, apices of setulae obtuse to sub-acute. *Lamellar trama* composed of thin-walled hyphae, 4–5 µm diam., inamyloid to faintly dextrinoid. *Pileal trama* hyphae 4–7.5 µm diam., thin-walled, faintly dextrinoid. *Pileipellis* a hymeniderm of two cell types: 1. common *Siccus*-type broom cells, hyaline, inamyloid, cylindrical, clavate, sometimes thick-walled, main body 13.5–22 × 5–9 µm, with multiple apical erect to slightly divergent thick-walled setulae, 4–6(–8) × 1–1.5 µm, and; 2. moderately common lanceolate setae, 50–130(–166) µm length, 4–6 µm mid-shaft diam., mostly thick-walled, up to 2 µm thick, rarely with cross-walls, apices acute, bases bulbous to boot-shaped. *Pleurocystidia* absent. *Stipe trama* dextrinoid, composed of parallel hyphae, 5–6 µm diam. *Caulosetae* very common, inamyloid, lanceolate, with thick walls to 1.5 µm, occasionally forked or branched 30–95(–200) µm, and rarely stellate, apices acute and bases broad and irregular to boot-shaped, branches to 45 µm length; and occasional thick-walled, blunt, irregular caulocystidia, 20–35 × 10 µm. *Clamp connections* present in all tissues. (Figure 4)

Other specimens examined. QUEENSLAND: Gap Creek Reserve, Brisbane, 5 Jan. 2008, *A.B. Cribb* Cribb-246 (BRI AQ1023825) and Cribb-249 (BRI AQ1023828); Mt Coot-tha, Brisbane, 24 Mar. 2021, *N. Fechner* NAF210304 (BRI AQ1021623); Irvinebank Hotel, Herberton, 20 Feb. 2001, *P.I. Forster, R. Booth & A.M. Young* PIF26879 (BRI AQ669468); Rex Range, Julatten, 1 Dec. 2001, *P.I. Forster, R. Booth & A.M. Young* PIF27894 (BRI AQ553476); Townsville, 28 Feb. 1997, *B.A. Fuhrer* 2084 (MEL 2037493); Davies Creek National Park, 13 Feb. 2021, *F.E. Guard, R. Palmer & T. Lebel* F2021058 (BRI AQ1033129); Clacherty Rd, Julatten, 17 Feb. 2021, *T. Lebel & J. Dearnaley* F2021072 (BRI

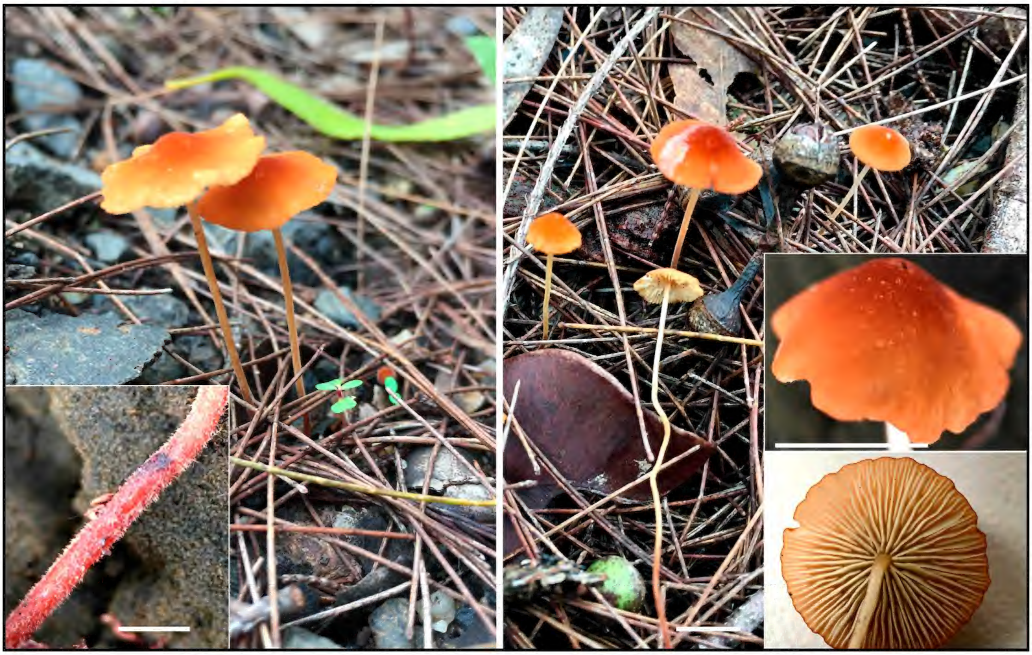

Figure 3. *Marasmius australotrichotus* (F2021058) field photo of sporing bodies. Scale bar = 10mm. Inset image of stipe. Scale bar = 2mm. Inset images of pileal surface and lamellae. Scale bar = 10mm. Photographs F.E. Guard.

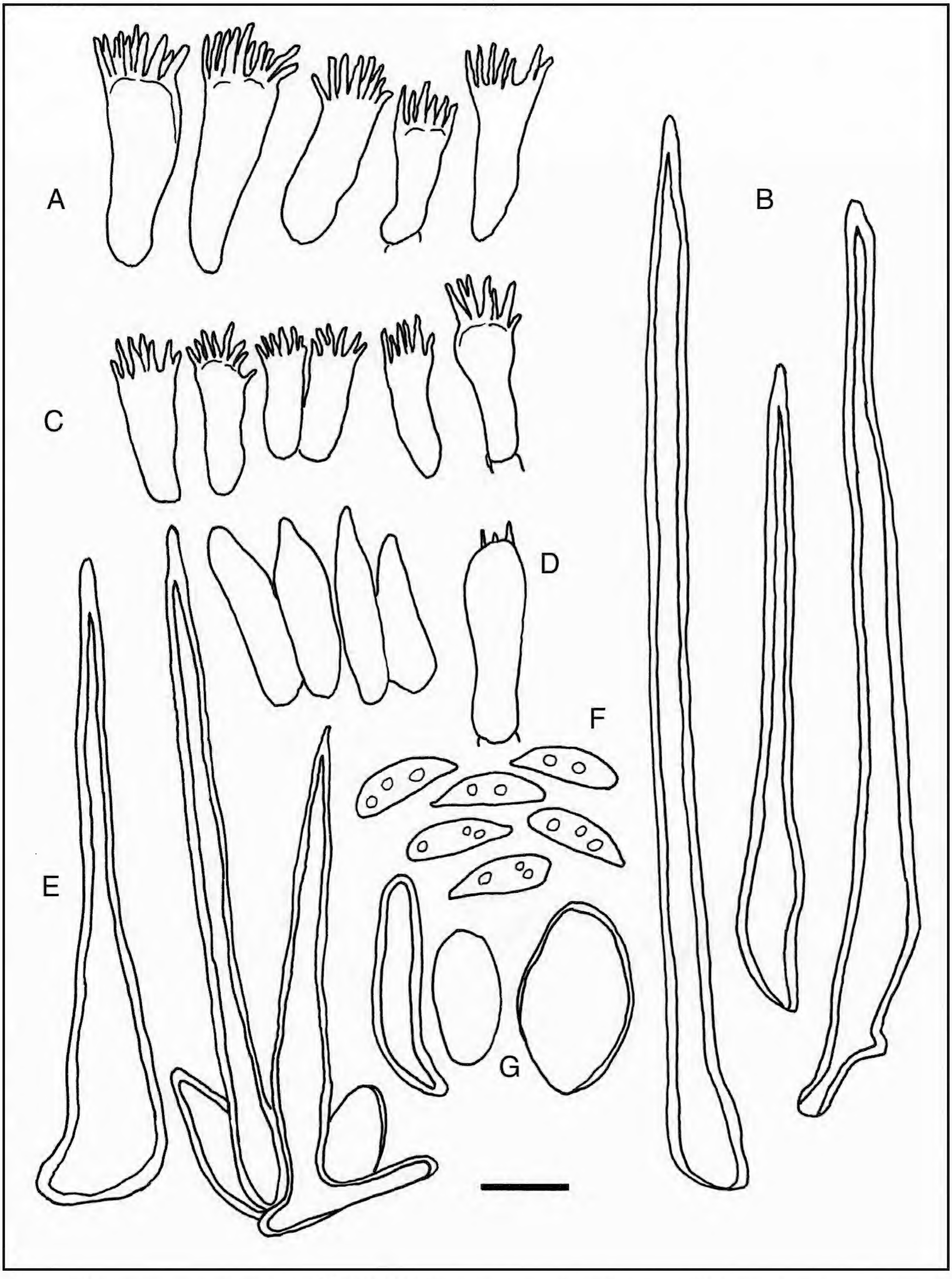

Figure 4. *Marasmius australotrichotus* (MDB F2022110) micromorphology. A – pileipellis *Siccus*-type broom cells, B – pileosetae, C – cheilocystidia, D – basidioles and basidium, E – caulosetae, F – spores, G – caulocystidia. Scale bar = 10 µm.

AQ1033131); The Fort Bushland Reserve, Oxley, Brisbane, 25 Mar. 2017, *M. Prance* 20170327MP4 (BRI AQ1023218); Meiers Rd, Indooroopilly, Brisbane, 16 Feb. 1998, *A.M. Wood* AMW1F (BRI AQ662716). NORTHERN TERRITORY: Palmerston, 21 Jan. 2014, *G.M. Bonito, M.D. Barrett, T. Lebel & C.N. Barrett* GMB469 (MEL 2382816).

Habit, habitat & distribution. Generally single, rarely caespitose, occurring in groups on leaf litter in *Eucalyptus/Acacia/Allocasuarina* forests. Also occurring on grassy road verges and in mulched garden beds from tropical to subtropical habitats. The species occurs in native vegetation but is also moderately common in suburban and disturbed areas. It has been found in Far North Queensland from Julatten to Townsville, South East Queensland, suburban Brisbane, and the Top End region of the Northern Territory.

Conservation status. Because of the wide distribution across multiple habitat types, *M. australotrichotus* is not considered to be under threat.

Etymology. The epithet is from the Latin *australis*, referencing its southerly global distribution, and acknowledges its close morphological and phylogenetic relationship to *Marasmius trichotus* (Corner 1996).

Notes. *Marasmius australotrichotus* has macroscopic features resembling the well-known Australian temperate species, *M. elegans* (Cleland) Grgur. However, *M. australotrichotus* has long, thin, velutinous stipe and small, velutinous orange-brown pileus, whereas *M. elegans* (Grgurinovic 1997; Bougher & Syme 1998) is more robust with smooth stipe 20–50 × 3–5 mm, (25–60(–80) × 0.5–1 mm in *M. australotrichotus*) and smooth pileus 12–50 mm diam. (10–40 mm diam. in *M. australotrichotus*), making them distinguishable in the field. *Marasmius elegans* also differs by lacking pileosetae and caulosetae. *Marasmius elegans* belongs to Sect. *Sicci*, ser. *Leonini* (sensu Singer 1976) and is phylogenetically distant from *M. australotrichotus* (Figure 2). The recently described *M. vagus* F.E.Guard, M.D.Barrett & Farid (Crous *et al.* 2020) is also similar, and has a similar distribution to *M. australotrichotus*, but is more robust (pileus 10–40 mm diam., stipe 3–5 mm diam., compared to pileus 5–15 mm diam. and stipe 0.5–1 mm diam. in *M. australotrichotus*), and always has white to cream stipe for its full length (reddish brown at the base in *M. australotrichotus*). It is also distinct phylogenetically as shown in Figure 2. Phylogenetic analysis of nrITS gene region using RAxML and Bayesian analyses places the new taxon in a distinct highly supported (BS 97% /PP 1.0) clade, with its sister species *M. neotrichotus* (Niveiro *et al.* 2018) from Argentina with low to moderate support (BS 56% /PP 0.97) (Figure 2).

Marasmius paratrichotus C.L.Grace, Desjardin & B.A.Perry, *Phytotaxa* 414(2): 75–77, figs 14, 15 (2019). *Type*: AFRICA. São Tomé, N 00°24.374’, E 06°37.092’, 17 April 2008, *D.E. Desjardin* DED 8248 (*holo*: SFSU). [MB 830250]

Background. *Marasmius paratrichotus* was described from the west African island nation of São Tomé and Príncipe (ST&P) by Grace *et al.* (2019). It forms a sister clade to *M. trichotus* (Figure 2) described from Singapore by Corner (1996). A revised description is provided here, incorporating details from the new Australian collections.

Pileus ~6 mm diam., orange, drying brownish, convex, broadly campanulate, to applanate, weakly striate, surface dull, dry, suede to velutinous. *Lamellae* adnexed, sub-distant (12–14) with 3 tiers lamellulae, white, non-marginate. *Stipe* 20–30 × 1 mm, central, cylindrical, cartilaginous, pale above and orange to brown in lower half, dry, pubescent with cream to orange strigose base. (Figure 5)

Basidiospores 10–11 × 3.5–4 µm, mean 10.5 × 3.5 µm, Q = 2.68–3.20, Q_m 2.96 (n = 30, measured from Christmas Island collection, narrow ellipsoid to lacrymoid, smooth, hyaline, inamyloid, thin-walled. Only one spore (11 × 4.5 µm) was found in the Kimberley collection. *Basidia* rare 18 × 5.5 µm. *Basidioles* abundant, narrow fusiform, ventricose-rostrate 21–25 × 5.5–7.5 µm. *Cheilocystidia* abundant *Siccus*-type broom cells, main body 7.5–22 × 5–7.5 µm, cylindrical, narrowly clavate, occasionally sub-globose, with multiple apical setules 2.5–7.5 × 0.5–1.5 µm, thin-walled, apices sub-acute. *Pleurocystidia* absent. *Pileal* and *lamellar trama* interwoven, hyphae 2–5 µm diam., thin-walled, hyaline, dextrinoid. *Pileipellis* a hymeniderm of two cell types: 1. *Siccus*-type broom cells, main body 7–20 × 3.5–9.5 µm, broadly clavate, cylindrical, sometimes thick-walled, refractile, occasionally lobed with multiple apical setules 2.5–7 × 1–2 µm, rarely forked, thin and thick-walled, and 2. *Pileosetae* 45–87 × 5–9 µm, cylindrical lower half, lanceolate distal half, thick-walled, walls 1.5 µm thick, bulbous base. *Stipe* trama dextrinoid, hyphae parallel, 5–7.5 µm diam. *Caulosetae* 41–85(–140) × 5.5–8.5 µm, lanceolate, occasionally geniculate, with bulbous or boot-shaped base to 20 µm wide, thick-walled to 1.5 µm, with some thick-walled septa (common in CI collection), inamyloid becoming yellowish-brown with maturity. *Caulocystidia* of two types: 1. uncommon *Siccus*-type broom cells in upper stipe, main body 8.5–14 × 5–6.5 µm, clavate to cylindrical, with sparse apical setules 3–7 × 0.5–1 µm, occasionally forked, usually thin-walled, (not observed in CI collection); and 2. rare, smooth, irregular thin-walled caulocystidia 15–21 × 6.5–10 µm. *Clamp connections* present in all tissues. (Figure 6)

Specimens examined. WESTERN AUSTRALIA: Theda Station, north Kimberley, 25 Jan. 2003, *M.D. Barrett* MDB F26/03 (PERTH 09594582); AUSTRALIAN TERRITORY: Christmas Island, Territory Day Park Nature Trail loop track, 18 Feb. 2016, *N.L. Bougher & K. Ruthrof* NLB 1255 (PERTH 08827117).

Notes. This species has only been found twice in Australia and its Territories. However, the remoteness of its tropical distribution means little survey effort has been made in other likely habitats. The addition of two collections (GenBank ON715786 & OQ725928) that are >99% similar to the ST&P collection, (GenBank KX953749 Grace *et al.* 2019), in the nrITS region is important in confirming the validity of the species as distinct from *M. trichotus*. *Marasmius paratrichotus* is morphologically similar to *M. trichotus*, which has an Asian and Oceania distribution including Thailand (Wannathes *et al.* 2009) and Papua New Guinea (Desjardin & Horak 1997). *Marasmius paratrichotus* is also very similar to *M. australotrichotus* and is morphologically differentiated only by a shorter, paler stipe (20–30 mm

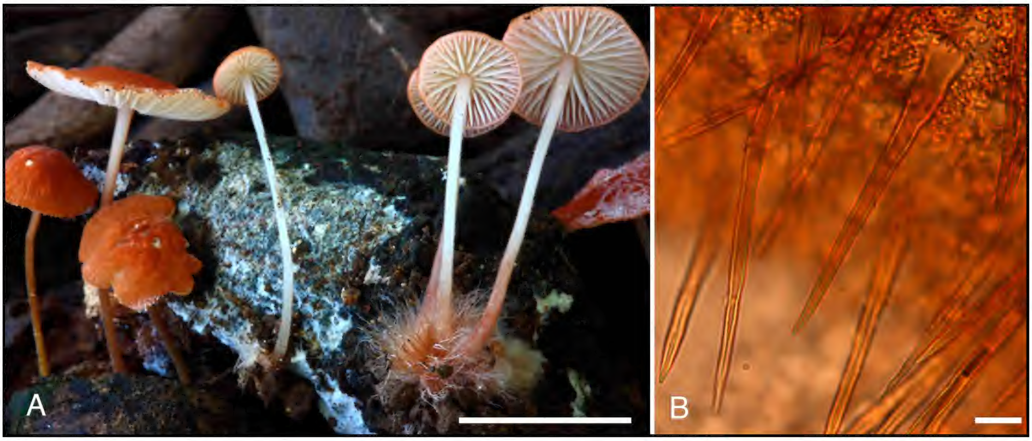

Figure 5. *Marasmius paratrichotus* (NLB 1255) A – sporing bodies in situ, scale bar =10 mm and B – pileosetae. Scale bar =10 µm. Photographs N.L. Bougher.

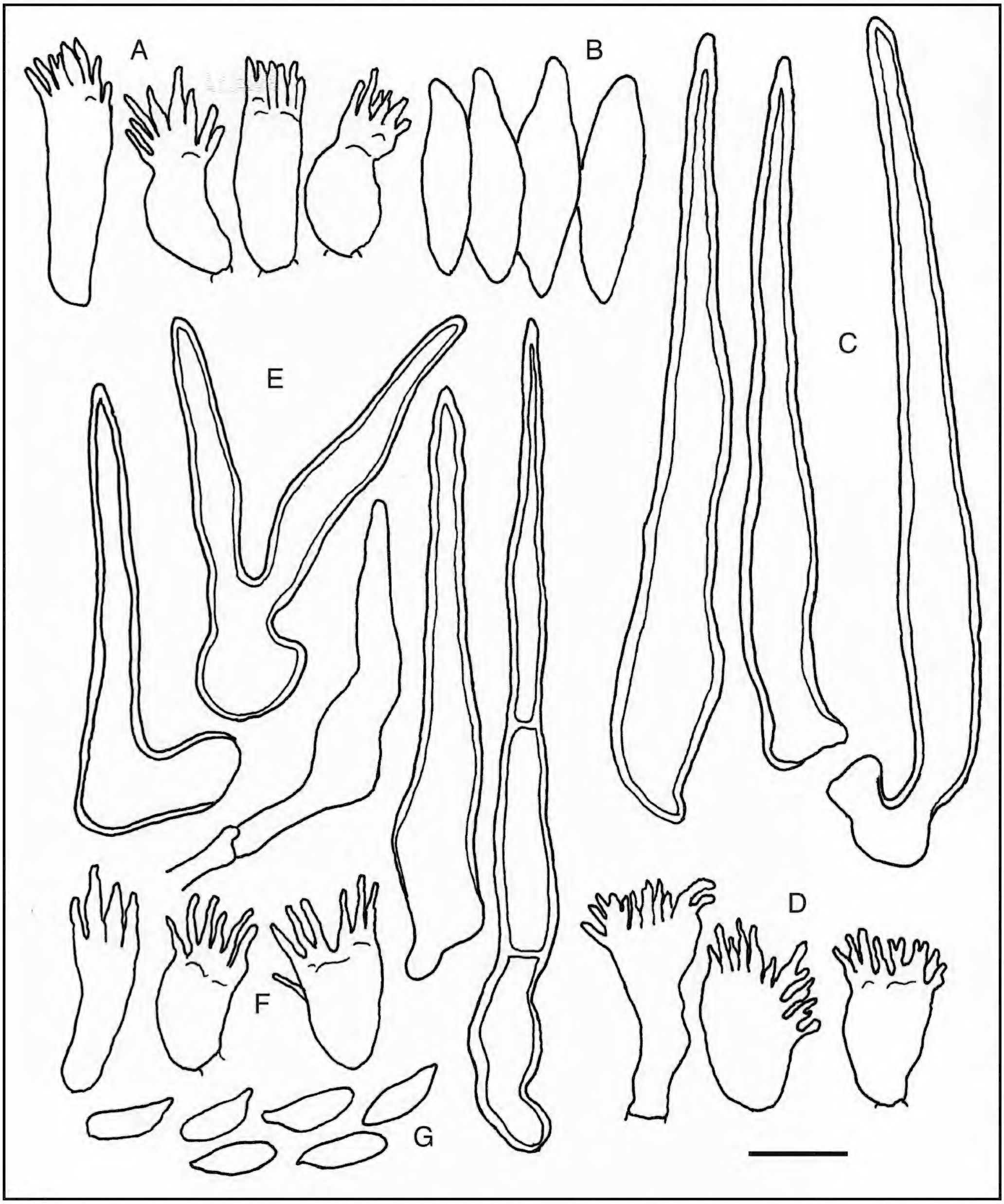

Figure 6. *Marasmius paratrichotus* (MDB F26/03 and NLB 1255) micromorphology. A – cheilocystidia, B – basidioles, C – pileosetae, D – pileipellis *Siccus* type broom cells, E –caulosetae, F – caulocystidia, G – spores. Scale bar = 10 µm.

cf. 25–80 mm in *M. australotrichotus*), white (*cf.* cream in *M. australotrichotus*) lamellae and slightly smaller spores (mean 10.5 µm (CI), 11.3 µm (ST&P) *cf.* 12 µm in *M. australotrichotus*). Should the distribution of the two taxa be found to overlap, care will be needed to separate them in the field. Phylogenetically, they form two distinct well-supported, non-sister clades (Figure 2).

Informative morphological characters used by Grace *et al.* (2019) in determining their new species in comparison to *M. trichotus* are: 1. Pileosetae are generally shorter in *M. paratrichotus* (<125 µm vs up to 300 µm and up to 1000 µm on pileal margin in *M. trichotus*); 2. while spores overlap in size, they are generally shorter in *M. paratrichotus* (mean 10.5 × 3.5 µm (CI) and 11 × 4.3 µm (ST&P) vs 12.5 × 3.5 µm); and 3. the occurrence of caulocystidia in the form of *Siccus*-type broom cells, while rare, is a particular feature of *M. paratrichotus* and not *M. trichotus*. However, these were not found in the CI specimen.

Corner (1996) described the stipe of *M. trichotus* as 'wholly puberulous, scurfy', yet did not mention lanceolate caulosetae in his description of the taxon and lanceolate caulosetae were not found in re-examination of the type specimen of *M. trichotus* by Niveiro (2018). Instead, he described caulocystidia consisting of modified broom cells with a narrow basal body and 2–6 setiform projections 45–70 µm long. Desjardin (1997), however, described lanceolate caulosetae up to 1000 µm long in the montane rainforest specimens of *M. trichotus* from Papua New Guinea, and Wannathes *et al.* (2009) found them to be 22–213 × 4–7 µm in the Thai collection. Caulosetae in *M. paratrichotus* are of overlapping, but generally shorter length than in *M. trichotus* (41–170 × 5.5–10.5(–14) µm), lanceolate, occasionally geniculate.

We note that the two Indian collections identified here as *M.* aff. *trichotus* (Dutta unpubl., GenBank MF189039 & MF189040) show greater similarity in nrITS analysis to *M. paratrichotus* than to *M. trichotus* from Thailand (99.09 & 99.18% vs 97.2 to 97.53% in this study). However, they remain on a separate branch in both Bayesian and Maximum Likelihood (RAxML) analyses of the nrITS region. It was argued by Grace *et al.* (2019) that the Indian sequences identified as *M. trichotus* were misidentified and that they represented *M. paratrichotus*. With the addition of the two sequences from the Australian region in this study, molecular differences remain, and indicate that the Indian specimens may represent yet another taxon, separate from both *M. paratrichotus* and *M. trichotus.*

Discussion

Support for monophyly of the traditional sect. *Sicci* (within the *Globulares*-*Sicci* complex), subsect. *Siccini*, ser. *Spinulosi* and *Atrorubentes* was low as noted in the introduction. Members of ser. *Atrorubentes*, *Haematocephali* and *Leonini* lay within the broader ser. *Spinulosi* clade. In 2020 Oliveira *et al.* proposed a new supra-specific classification using phylogenetic, ecological and morphological characteristics to recognise more stringent groups within sect. *Globulares*. A number of new taxa have been described since that proposal and this study includes some of them (*M. australotrichotus*, *M. neotrichotus*, *M. paratrichotus* and *M.* aff. *trichotus* among others), in the phylogeny (Figure 2). This has been an opportunity to test the newly raised subsections and series. Separating the 'cohaerens' group of northern hemisphere setose species of *Marasmius* is logical. This was catered for by raising subsect. *Spinulosi*, ser. *Cohaerentes* (Oliveira *et al.* 2020). However, the next phylogenetic group consisted of a set of unrelated subclades, termed subsect. *Incertae sedis*. Oliveira's series *Atrorubentes* (sensu Oliveira *et al.* 2020), includes species traditionally in ser. *Atrorubentes* and ser. *Spinulosi.* While all the species in this study fall into ser. *Atrorubentes* sensu Oliveira *et al.* (2020), with high phylogenetic support, morphologically they are very diverse. Members in the 'trichotus' group – *M. trichotus*, *M. australotrichotus*, *M. paratrichotus* and *M. neotrichotus* – are all similar, including having small to medium basidiomes (4–15(–23) mm diam.), medium hyaline clavate spores, (9–)10–13(–15) × 3–4.5 µm. They have setae on pileus and stipe, but not in the hymenium and lack pleurocystidia. Caulocystidia (as defined in this paper) are sparse and inconspicuous or absent. These common features suggest that this group could form another series. However, further collections and data are needed.

Marasmius australotrichotus has a distribution in tropical and subtropical Queensland and the Northern Territory (Figure 7), which mirrors some other saprotrophic species of fungi, e.g., *M. vagus* (Crous *et al*. 2020). While it is found in rainforest margins (QLD: Julatten) and *Eucalyptus*/*Allocasuarina* forest (QLD: Davies Creek National Park), it is also found in much more disturbed areas, such as road verges, suburban lawns and even mulched gardens (e.g., Kuranda, Indooroopilly, Mt Coot-tha). It has been mistaken for the more common *M. elegans*, but examination with a hand lens readily separates the two (see *Notes* above). Aerial dispersal of spores is likely for *M. australotrichotus*; however, human movement of the species cannot be discounted.

The distribution of *M. paratrichotus* is more unusual and intriguing, with known populations almost 11,000 km apart on São Tomé, Gulf of Guinea in West Africa and Christmas Island, near Java in the Indian Ocean, with a further population another 2,300 km east in the Kimberley, WA. Figure 7 shows this distribution in relation to its sister species. To date, it has been found on woody debris under baobabs (*Adansonia* sp.) in a coastal xerophytic habitat (ST&P) (Grace *et al*. 2019), among leaf litter in tropical monsoon savanna grass/lawn (WA - this study, M.D. Barrett) and on rotting wood in marginal rainforest (CI - this study, N.L. Bougher). All three sites are in tropical latitudes (0–14°S). It would appear from this study and earlier work that habitat is not an informative feature within the clade or in distinguishing between *M. paratrichotus* and its sister, *M. trichotus.*

São Tomé and Principe are ancient volcanic islands in the Cameroon Volcanic Line, which appeared about 30 Mya. Volcanism persisted until recently (0.1–0.036 Mya) (Melo *et al*. 2022). There is a history of repeated colonisation and extinction of organisms, which have largely originated from continental Africa. Dispersal to the islands is postulated to have been aerial (wind borne), avian, or by rafts of vegetation floating in freshwater plumes from the three large rivers that drain into the Gulf of Guinea, namely the Congo, Ogooué, and Niger Rivers (Ceríaco *et al*. 2022; Desjardin & Perry 2022). According to Desjardin and Perry (2022), the rich fungal biodiversity of tropical Africa is understudied, and under-documented. Antonin's (2007) monograph of *Marasmius* of tropical Africa, includes collections from the west African nations of Cameroon, Sierra Leone and Democratic Republic of Congo. He described five species in sect. *Sicci,* ser. *Spinulosi*, none of which are morphologically similar to *M. paratrichotus* and none were sequenced. Further sampling across continental tropical

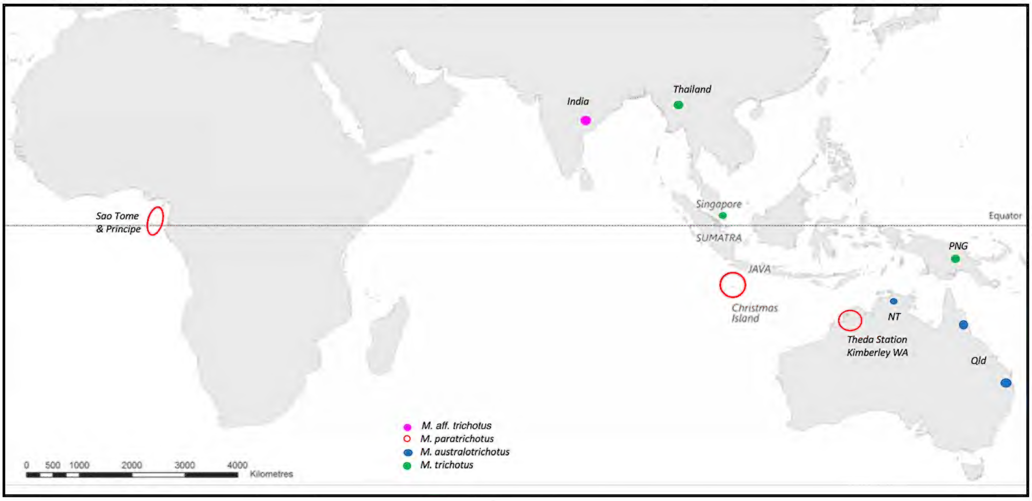

Figure 7. Global distribution of *Marasmius trichotus*, *M.* aff. *trichotus*, *M. paratrichotus* and *M. australotrichotus*.

Africa may produce relatives of species from São Tomé including *M. paratrichotus*, but otherwise its nearest known relatives are in India.

Christmas Island is another ancient oceanic volcanic island 350 km south of Java, having arisen 44 Mya (James & McAllan 2014). Like other isolated islands it has a high degree of endemism (James *et al*. 2019). It is also the breeding ground for a number of tropical pelagic birds, e.g., Abbott's booby, which ranges widely across the Indian Ocean and, in recent times, bred on some of the western Indian Ocean islands near Madagascar (Carboneras 1992). Other migratory shorebirds occasionally visit the island from the East Asian-Australasian flyway (James & McAllan 2014). These and other visiting terrestrial birds may have carried spores of *M. paratrichotus* to the island. Other possible means of spore dispersal include the prevailing winds, with the northwest monsoon (December to April) from the Indo-Malayan region, and the dry season (May to November) south east trade winds from Australia (James & McAllan 2014).

The Kimberley region of northwest Australia has a monsoonal climate and rich fungal diversity much of which remains to be studied (Barrett 2018). It is part of the Australian Monsoon Tropics (AMT) biome, which extends from WA across the Top End region of Northern Territory to Cape York and shares a number of fungal flora across that region, e.g., *Marasmius vagus* (Crous *et al*. 2020). *Marasmius australotrichotus* occurs in NT and far north Qld but has not yet been discovered in WA. It is quite possible that both *M. australotrichotus* and *M. paratrichotus* will be found in suitable habitats across the AMT. Further surveys may produce new populations of both taxa there or on other islands across the Indian Ocean.

The possibility of human dispersal cannot be discounted, with exploration, settlement, trade and more recently tourism ensuring a constant flow of humans around the globe, including even these seemingly remote and distant places. Molecular data show only two base pairs difference between the nrITS sequences from the three locations of *M. paratrichotus*. It is impossible to determine from such a small sample where the species originated. Further surveys are needed to extend knowledge of the distribution of both taxa.

Acknowledgements

We thank curatorial staff at the Queensland Herbarium (BRI), National Herbarium of Victoria (MEL) and Western Australian Herbarium (PERTH) for their assistance. We acknowledge funding sources including the Australasian Systematic Botany Society for financial support in fieldwork and molecular analysis and ABRS grant 4-EHOJ161 for field work assistance in Qld and NSW. We acknowledge assistance from Dr Katinka Ruthrof (then Murdoch University) and project staff of MINTOPE (Mining to Plant Enterprises Project), Alasdair Grigg and staff at CI Parks Australia, and Christmas Island Phosphates (Phosphate Resources Ltd.). Cecilia Myers is thanked for assistance with field work in the Kimberley in 2003. Sincere thanks are extended to referees for their very useful comments.

References

Antonin, V. (2007). *Fungus flora of tropical Africa* (ed. Degreef, J., Vol. 1). (National Botanic Garden, Belgium.)

Antonin, V. & Noordeloos, M. (2010). *A monograph of marasmioid and collybioid fungi in Europe*. (IHW-Verlag 2010, Eching, Berlin.)

Antonín, V., Ryoo, R. & Shin, H-D. (2012). Marasmioid and gymnopoid fungi of the Republic of Korea. 4. *Marasmius* sect. *Sicci*. *Mycological Progress* 11: 615–638.

Barrett, M.D. (2018). Fungi of the Kimberley. *In*: McGlashan, H., Coate, K., Gresham, J. & Hart, R. (eds.) *The natural world of the Kimberley*. pp. 38–42. (Kimberley Soc. Inc., Perth.)

Bougher, N.L. & Syme, K. (1998). *Fungi of southern Australia*. (University of Western Australia Press: Perth.)

Carboneras, C. (1992). *Family Sulidae (Gannets and Boobies). In*: del Hoyo, J., Elliott, A. & Sargatal, J. (eds.) *Handbook of the birds of the world* (Vol. 1): *Ostrich to Ducks.* pp. 312–325. (Lynx Edicions, Barcelona.)

Ceríaco, L.M.P., Santos, B.S., de Lima, R.F., Bell, R.C., Norder, S.J. & Melo, M. (2022). Physical geography of the Gulf of Guinea oceanic islands. *In*: Ceríaco, L.M.P., de Lima, R.F., Melo, M., & Bell, R.C. (eds.) *Biodiversity of the Gulf of Guinea oceanic islands: science and conservation*. pp. 13–36. (Springer International Publishing, Cham, Switzerland.)

Clémençon H. (1982). Kompendium der Blätterpilze. II. *Marasmius*. *Zeitschrift für Mykologie* 48: 3–16.

Corner, E. (1996). The agaric genera *Marasmius, Chaetocalathus, Crinipellis, Heimiomyces, Resupinatus, Xerula* and *Xerulina* in Malesia. *Nova Hedwigia, Beihefte* 111: 1–175.

Crous, P.W., Wingfield, M. & Chooi, Y.-H. (2020). Fungal Planet description sheets: 1042–1111, *Marasmius vagus* F.E. Guard, M.D. Barrett & Farid sp. nov. (sheet1091). *Persoonia* 44: 301–459. Retrieved from https://www.fungalplanet.org/content/pdf-files/FungalPlanet1091.pdf

Desjardin, D.E. & Horak, E. (1997). *Marasmius* and *Gloiocephala* in the south Pacific region: Papua New Guinea, New Caledonia and New Zealand taxa. Part 1: Papua New Guinea and New Caledonia taxa. *In*: Petrini, O., Petrini, L.E. & Horak, E. (eds.) *Taxonomic monographs of Agaricales 2, Bibliotheca Mycologica* 168: 1–152.

Desjardin, D.E. & Perry, B.A. (2022). Fungi of São Tomé and Príncipe Islands: basidiomycete mushrooms and allies. *In*: Ceríaco, L.M.P., de Lima, R.F., Melo, M., & Bell, R.C. (eds.) *Biodiversity of the Gulf of Guinea oceanic islands: science and conservation*. pp. 189–216. (Springer International Publishing, Cham, Switzerland.)

Gardes, M. & Bruns, T. (1993). ITS primers with enhanced specificity for basidiomycetes - application to the identification of mycorrhizae and rusts. *Molecular Ecology* 2(2): 113–118.

Grace, C.L., Desjardin, D.E., Perry, B.A. & Shay, J.E. (2019). The genus *Marasmius* (Basidiomycota, Agaricales, Marasmiaceae) from Republic of Sao Tome and Principe, West Africa. *Phytotaxa* 414(2): 55–104.

Grgurinovic, C.A. (1997). *Larger fungi of South Australia*. (The Botanic Gardens of Adelaide and State Herbarium: Adelaide.)

Huelsenbeck, J.P. & Ronquist, F. (2001). MRBAYES: Bayesian inference of phylogenetic trees. *Bioinformatics* 17(8): 754–755.

James, D., Green, P.T., Humphreys, W. & Woinarski, J. (2019). Endemic species of Christmas Island, Indian Ocean. *Records of the Western Australian Museum* 34(2): 55–114.

James, D.J. & McAllan, I.A. (2014). The birds of Christmas Island, Indian ocean: a review. *Australian Field Ornithology* 31: S1–S175 (Supplement).

Katoh, K. & Standley, D.M. (2013). MAFFT multiple sequence alignment software version 7: improvements in performance and usability, *Molecular Biology and Evolution* 30(4): 772–780.

Kiyashko, A.A., Malysheva, E.F., Antonin, V., Svetasheva, T.Y. & Bulakh, E.M. (2014). Fungi of the Russian Far East 2. New species and new records of *Marasmius* and *Cryptomarasmius* (Basidiomycota). *Phytotaxa* 186(1): 1–28.

Melo, M., Ceríaco, L.M. & Bell, R.C. (2022). Biogeography and evolution in the oceanic islands of the Gulf of Guinea. *In*: *Biodiversity of the Gulf of Guinea oceanic islands.* pp. 141–170. (Springer International Publishing, Cham, Switzerland.)

Niveiro, N., Michlig, A., Ramírez, N.A., Salvador-Montoya, C.A., Pérez, M.L., Albertó, E.O. & Antonín, V. (2018). Two new setose species of Marasmius from the Paraná riparian forest in Argentina. *Cryptogamie, Mycologie* 39(4): 483–506.

Oliveira, J.J.S., Sanchez-Ramirez, S. & Capelari, M. (2014). Some new species and new varieties of *Marasmius* (Marasmiaceae, Basidiomycota) from Atlantic rainforest areas of São Paulo State, Brazil. *Mycological Progress* 13(3): 923–949.

Oliveira, J.J.S., Moncalvo, J.M., Margaritescu, S. & Capelari, M. (2020). A morphological and phylogenetic

evaluation of *Marasmius* sect. *Globulares* (Globulares-Sicci complex) with nine new taxa from the neotropical Atlantic Forest. *Persoonia* 44(1): 240–277.

Royal Botanic Gardens, Edinburgh (1969). *Flora of British fungi: colour identification chart*. (Her Majesty's Stationery Office: Edinburgh.)

Shay, J.E., Desjardin, D.E., Perry, B.A., Grace, C.L. & Newman, D.S. (2017). Biodiversity and phylogeny of *Marasmius* (Agaricales, Basidiomycota) from Madagascar. *Phytotaxa* 292(2): 101–149.

Singer, R. (1976) Marasmieae (Basidiomycetes - Tricholomataceae). *Flora Neotropica* 17: 1–347.

Singer, R. (1986) The Agaricales in modern taxonomy. (Koenigstein, Koeltz scientific books: Federal Republic of Germany)

Stamatakis, A. (2014). RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30(9): 1312–1313.

Tan, Y.-S., Desjardin, D., Perry, B., Vikineswary, S. & Noorlidah, A. (2009). *Marasmius* sensu stricto in peninsular Malaysia. *Fungal Diversity* 37: 9–100.

Vilgalys, R. & Hester, M. (1990). Rapid genetic identification and mapping of enzymatially amplified ribosomal DNA from several Cryptococcus species. *Journal of Bacteriology* 172(8): 4238–4246.

Wannathes, N., Desjardin, D., Hyde, K., Perry, B. & Lumyong, S. (2009). A monograph of *Marasmius* (Basidiomycota) from northern Thailand based on morphological and molecular (ITS sequences) data. *Fungal Diversity* 37: 209–306.

White, T.J., Bruns, T., Lee, S. & Taylor, J. (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. *PCR protocols: a guide to methods and applications* 18(1): 315–322.

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dbca.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01064

Nuytsia 34: 221–226

Published online 26 October 2023

Molecular analysis identifies a red seaweed common in the Swan Estuary as *Gracilaria transtasmanica* (Gracilariales: Gracilariaceae)

John M. Huisman[1], Giuseppe C. Zuccarello[2] & Showe-Mei Lin[3]

[1]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2]School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand
[3]Institute of Marine Biology, National Taiwan Ocean University, Keelung City 20224, Taiwcan, R.O.C.
[1]Corresponding author, email: John.Huisman@dbca.wa.gov.au

SHORT COMMUNICATION

Species of the red seaweed *Gracilaria* Grev. (Gracilariales: Gracilariaceae) can often display considerable infra-specific morphological variation, or conversely several cryptic species can be morphologically similar and only confidently identified by molecular methods. This second category includes a group of three species that have been recorded for the Australasian region: *Gracilaria sordida* Nelson, *G. chilensis* Bird, McLachlan & Oliveira and *G. transtasmanica* (M.Preuss, N.Muangmai & Zuccarello) Lyra, Iha, J.M.C.Nunes & C.C.Davis. *Gracilaria sordida* was described by Nelson (1987) to include plants that were often stringy or 'untidy', suggesting that earlier records were incorrectly attributed to forms of *G. secundata* (*sensu* May 1948) or *G. confervoides* (L.) Grev. (= *G. verrucosa* (Huds.) Papenf.). As noted by Nelson, the configuration of the spermatangial conceptacle differentiated *G. sordida* from both species. *Gracilaria sordida* was subsequently placed into synonymy with the earlier *G. chilensis* by Bird *et al.* (1990). Womersley (1996) recorded *G. chilensis* for south-eastern Australia, following Bird *et al.* (1990) in placing *G. sordida* in synonymy. *Gracilaria chilensis* in Australia was described as 'largely confined to river mouths or estuaries, as in Chile and New Zealand' (Womersley 1996: 25).

Molecular studies of New Zealand, Australian and Chilean specimens indicated that two morphologically inseparable species were present, one initially misidentified for New Zealand and Australia as *G. chilensis*, and the second actual *G. chilensis* from Chile and New Zealand, the latter including *G. sordida* (Cohen *et al.* 2004). The former was eventually described in a segregate genus as *Agarophyton transtasmanicum* (Preuss *et al.* 2020) before that genus was subsumed into *Gracilaria* by Lyra *et al.* (2021).

A species of *Gracilaria* is common in the Swan River estuary, Western Australia. This species has been recorded under various names: *G. confervoides* by Thomson (1946: 58) and Royce (1955: 44), *G. confervoides* f. *gracilis* (Stackh.) Grunow by May (1948: 27), *G. verrucosa* by Allender (1981: 22) and *G. comosa* Withell, A.Millar & Kraft by Astill and Lavery (2004). Royce (1955) described the estuary's *Gracilaria* as 'Among the macroscopic forms, *Gracilaria confervoides* is the most abundant, and grows thickly over the river bed at least as far upstream as the Causeway. The thallus is fine, much branched, cartilaginous and terete, or round in cross section, while the branches and branchlets

© Department of Biodiversity, Conservation and Attractions 2023

ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

are narrowed into fine filiform points.' Specimens in the Western Australian Herbarium date back to 1949 (PERTH 03969010) collected by R.D. Royce from the drift at South Perth. Indeed, *Gracilaria confervoides* was recorded in some of the earliest investigations of Western Australian seaweeds, and noted by Harvey (1855: 550) as 'abundant at Fremantle'. *Gracilaria confervoides* and *G. verrucosa* are both now referred to *Gracilariopsis longissima* (S.G.Gmelin) Steentoft, L.M.Irvine & Farnham, and according to Womersley (1996: 15) 'there now appears no reason to record *G. verrucosa* from southern Australia, and this taxon is probably confined to European coasts'. *Gracilaria confervoides* f. *gracilis* is now treated as *Gracilaria gracilis* (Stackh.) Steentoft, L.M.Irvine & Farnham, another northern hemisphere species, and May's (1948: 27) determination of the Swan Estuary specimens as that taxon is undoubtedly an error.

As morphology is inconclusive in distinguishing this group of species, we have undertaken a molecular analysis using *rbc*L sequences, which clearly places the Swan River entity in *Gracilaria transtasmanica* and not conspecific with any of the species to which it has previously been attributed (Figure 1). While this represents the first record for Western Australia and the Indian Ocean under this name, the species is clearly a long-term component of the native algal flora and should not be considered an introduction. The mitochondrial COI-5P barcode region was also sequenced from a specimen collected from the Swan Estuary but not vouchered. It showed a difference of seven synonymous bp differences to specimens from New Zealand and eastern Australia (Huanel *et al.* 2020; Preuss *et al.* 2020)(data not shown), suggesting a long separation.

Given the species has apparently been present in Western Australia for at least decades, if not centuries, could there be an earlier-named species based on a Western Australian type? One species is clearly closely related, *Gracilaria comosa* Withell, A.Millar & Kraft (in Withell *et al.* 1994). The two species share a similar habit, structure and spermatangial arrangement. According to Withell *et al.* (1994), *G. comosa* is characterised by 'its abundantly divided, terete and very narrow branches and laterals which, except for the larger branches, are slightly to markedly constricted at their bases'. This was also noted in specimens in the Western Australian Herbarium from Jurien Bay (PERTH 08846758, PERTH 08846731) and from Dongara (PERTH 01663887), the latter a paratype from adjacent to the Port Denison type locality. In the description of *G. transtasmanica*, Preuss *et al.* (2020) noted branches and branchlets were 'not, or only slightly, basally constricted'. This was also true of the Swan Estuary specimens. In addition, while tetrasporangia were not recorded by Preuss *et al.* (2020), the Swan Estuary specimens had scattered tetrasporangia, whereas those of *G. comosa* occur in raised nemathecia. While we do not have molecular data for *G. comosa*, we are satisfied that the branches with marked basal constrictions and the disposition of tetrasporangia clearly distinguish this species from *G. transtasmanica*.

Gracilaria transtasmanica belongs to a group of species (the *Agarophyton* of Gurgel *et al.* 2018) that are typically found in estuaries and harbours, and includes the invasive *G. vermiculophylla* (Ohmi) Papenf. that has spread from Japan to numerous locations in the northern hemisphere (Gurgel *et al.* 2018). The distribution of *G. transtasmanica* might suggest similar invasive tendencies, however if this is the case for the Swan Estuary population, given multiple early records, the initial introduction must have been decades, if not centuries ago.

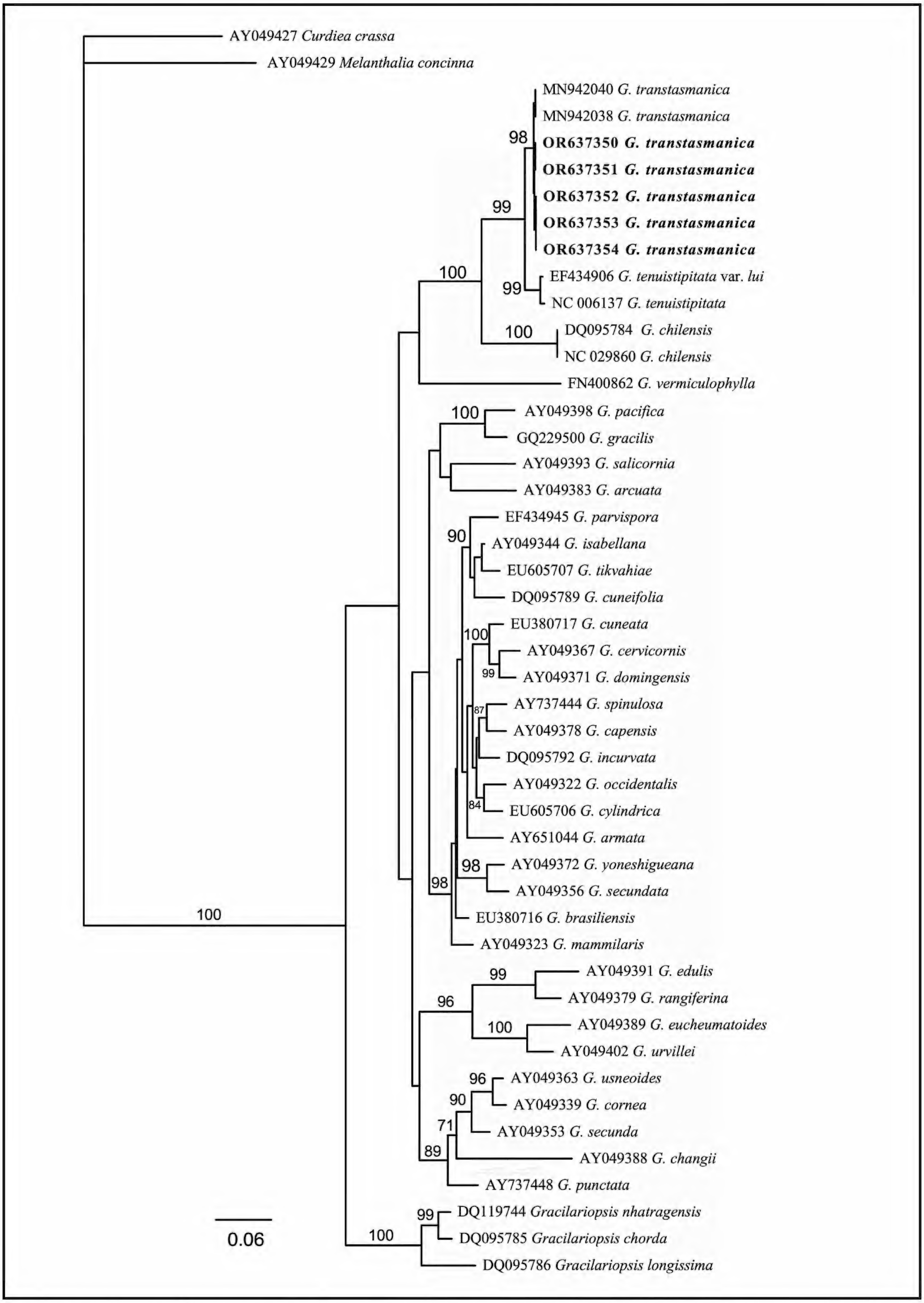
AY049427 *Curdiea crassa*
AY049429 *Melanthalia concinna*
MN942040 *G. transtasmanica*
MN942038 *G. transtasmanica*
98
OR637350 *G. transtasmanica*
OR637351 *G. transtasmanica*
OR637352 *G. transtasmanica*
99
OR637353 *G. transtasmanica*
OR637354 *G. transtasmanica*
100
EF434906 *G. tenuistipitata* var. *lui*
99
NC 006137 *G. tenuistipitata*
100
DQ095784 *G. chilensis*
NC 029860 *G. chilensis*
FN400862 *G. vermiculophylla*
100
AY049398 *G. pacifica*
GQ229500 *G. gracilis*
AY049393 *G. salicornia*
AY049383 *G. arcuata*
EF434945 *G. parvispora*
90
AY049344 *G. isabellana*
EU605707 *G. tikvahiae*
DQ095789 *G. cuneifolia*
EU380717 *G. cuneata*
100
AY049367 *G. cervicornis*
99
AY049371 *G. domingensis*
AY737444 *G. spinulosa*
87
AY049378 *G. capensis*
DQ095792 *G. incurvata*
AY049322 *G. occidentalis*
84
EU605706 *G. cylindrica*
AY651044 *G. armata*
98
AY049372 *G. yoneshigueana*
98
AY049356 *G. secundata*
100
EU380716 *G. brasiliensis*
AY049323 *G. mammilaris*
99
AY049391 *G. edulis*
AY049379 *G. rangiferina*
96
100
AY049389 *G. eucheumatoides*
AY049402 *G. urvillei*
96
AY049363 *G. usneoides*
90
AY049339 *G. cornea*
71
AY049353 *G. secunda*
89
AY049388 *G. changii*
AY737448 *G. punctata*
99
DQ119744 *Gracilariopsis nhatragensis*
0.06
100
DQ095785 *Gracilariopsis chorda*
DQ095786 *Gracilariopsis longissima*

Figure 1. Maximum-likelihood tree of *rbc*L sequences of various *Gracilaria* and *Gracilariopsis* species, with GenBank accession numbers. Swan Estuary specimens in bold. Tree and model selection produced in IQTREE2 (1278bp dataset) (Minh *et al.* 2020). 500 bootstrap replicates in % shown on significant branches. *Curdiea crassa* and *Melanthalia concinna* selected as outgroups.

Gracilaria transtasmanica (M.Preuss, N.Muangmai & Zuccarello) Lyra, Iha, J.M.C.Nunes & C.C.Davis, *Molec. Phylogen. Evol.* 165(107294):10 (2021).

Basionym: *Agarophyton transtasmanicum* M.Preuss, N.Muangmai & Zuccarello, *Phycologia* 59(3): 240 (2020).

Type: Whanganui River mouth, Whanganui, North Island, New Zealand, 18 December 2018, *M. Preuss & G.C. Zuccarello* (*holo*: WELT A033798!; *iso*: WELT A033797!). Genbank Accession numbers: cox1: MN942037, ITS1: MN942043, *rbc*L: MN942038.

[*Gracilaria chilensis auct non* C.J.Bird, McLachlan & E.C.Oliveira: Womersley 1996: 23]

[*Gracilaria confervoides auct non* (L.) Grev.: Thomson 1946: 58; Royce 1955: 44]

[*Gracilaria confervoides* f. *gracilis auct non* (Stackh.) Grunow: May 1948: 27]

[*Gracilaria verrucosa auct non* (Huds.) Papenf.: Allender 1981: 22]

[*Gracilaria comosa auct non* Withell, A.Millar & Kraft: Astill & Lavery 2004: 12, 13]

Description. Thallus greenish to dark red-brown, often drying black, 10–35 cm high, with 1-several fronds arising from a discoid holdfast, irregularly branched with percurrent main axes and numerous lateral branches of varying lengths, apices acute; branches terete, 0.4–1 mm diam., tapering to 0.2–0.4 mm diam. close to the apices, not basally constricted. Structure uniaxial, with a slightly protruding apical cell, pseudoparenchymatous, axial filament not obvious in mature portions, with an abrupt transition in cell size from cortex to medulla; cortex with 2–6 cell layers, outer cells ovoid (often slightly palisade like) and 4–10 µm broad in surface view, L/D 1.5–2.5 in section; medulla 6–12 cells across, inner medullary cells ovoid, 70–270 µm diam., thick walled with numerous secondary pit-connections. Male plants not seen. Cystocarps scattered, protuberant, sessile, hemispherical, conical to globular and basally constricted, 500–800 µm diam.; pericarp 80–100 µm thick, with anticlinal rows of 6–9 cells, ostiolate. Tetrasporangia scattered in the cortex, basally pit-connected, ovoid, 40–50 µm long, 30–36 µm diam., cruciately to almost tetrahedrally divided. (Figure 2)

Diagnostic features. Amongst the local species *G. transtasmanica* can be distinguished by its thallus being irregularly branched with long main branches and numerous laterals of varying lengths that lack basal constrictions, and tetrasporangia scattered in the cortex.

Specimens examined. WESTERN AUSTRALIA: Mouth of Margaret River, drift, 3 Mar. 1965, *B.M. Allender s.n.* (PERTH 06997368); Swan River Estuary, Claremont Jetty, 22 Aug. 1968, *B.M. Allender s.n.* (PERTH 07008287); Swan River Estuary, The Springs, Belmont, 22 Aug. 1968, *B.M. Allender s.n.* (PERTH 07092245); Leschenault Inlet, near Vasse River, [sic, possibly Collie River], 1 m depth in sandy/muddy substrate, 18 Oct. 1976, *M.L. Cambridge s.n.* (PERTH 06997546); Nornalup Inlet, near channel, 2 Apr. 2015, *J.M. Huisman* 2.4.15.1.4 (PERTH 08854351); Canning Bridge, Mount Pleasant, 14 Sep. 2018, *J.M. Huisman* 4.9.18.1 A–D (PERTH 09571027; PERTH 09571108; PERTH 09571140. Genbank OR637350–OR637354); Matilda Bay, Swan River, 30 Mar, 1950, *W. McArthur s.n.* (PERTH 06997406); Swan River, at Guildford Grammar School, abundant, 6 Apr. 1971, *L. Mutton s.n.* (PERTH 07008201); South Perth, drift, 4 Sep. 1949, *R.D. Royce* 347 (PERTH 03969010); Dawesville, Harvey Estuary, 25 Feb. 1972, *G.G. Smith & E.P. Hodgkin s.n.* (PERTH 07040210; PERTH 09605843).

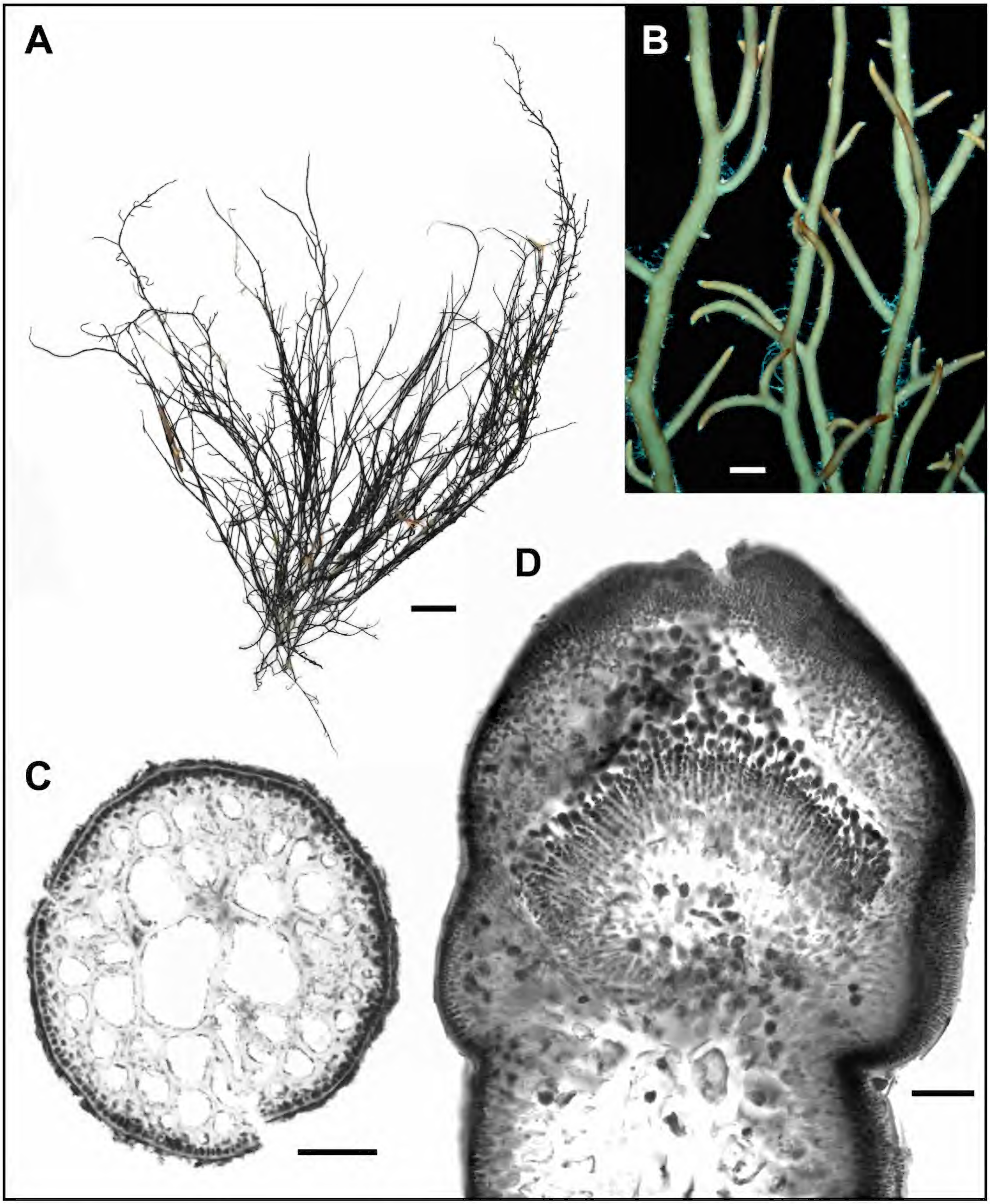

Figure 2. *Gracilaria transtasmanica*. A – pressed specimen showing irregular branching; B – detail of thallus, wet specimen; C – transverse section of branch, showing pseudoparenchmatous structure with abrupt transition between medulla and cortex; D – transverse section of cystocarp. Scale bars = 1 cm (A); 1 mm (B); 100 µm (C, D). Images from PERTH 09571140. Photographs by J.M. Huisman.

Distribution and habitat. North Island of New Zealand (Auckland, Foxton, Whanganui), Tasmania (Kingston Beach, Marion Bay), southern Australia (Glenelg, Hindmarsh Island, Phillip Island), and western Australia (Swan Estuary, Leschenault Inlet, Nornalup Inlet). Typically growing in sandy or muddy estuarine habitats, often attached to shells or loose lying.

Conservation status. This species is clearly widespread in estuarine habitats and is not threatened. Its historical presence in the Swan Estuary suggests it is not an introduction.

Acknowledgements

We thank the staff of the Western Australian Herbarium and acknowledge funding support from the Australian Biological Resources Study (Activity ID 4-G046WSD).

References

Allender, B.M. (1981). The distribution of benthic macroflora in the Swan River estuary, Western Australia. *Journal of the Royal Society of Western Australia* 4(1): 17–22.

Astill, H.L. & Lavery, P.S. (2004). Distribution and abundance of benthic macroalgae in the Swan-Canning Estuary, south-western Australia. *Journal of the Royal Society of Western Australia* 87: 9–14.

Bird, C.J., Nelson, W.A., Rice, E.L., Ryan, K.G. & Villemur, R. (1990). A critical comparison of *Gracilaria chilensis* and *G. sordida* (Rhodophyta, Gracilariales). *Journal of Applied Phycology* 2: 375–382. https://doi.org/10.1007/BF02180928

Cohen, S., Faugeron, S., Martínez, E.A., Correa, J.A., Viard, F., Destombe, C. & Valero, M. (2004). Molecular identification of two sibling species under the name *Gracilaria chilensis* (Rhodophyta, Gracilariales). *Journal of Phycology* 40: 742–747. https://doi.org/10.1111/j.1529-8817.2004.03203.x

Gurgel, C.F.D., Norris, J.N., Schmidt, W.E., Le, H.N. & Fredericq, S. (2018). Systematics of the Gracilariales (Rhodophyta) including new subfamilies, tribes, subgenera, and two new genera, *Agarophyton* gen. nov. and *Crassa* gen. nov. *Phytotaxa* 374(1): 1–23.

Harvey, W.H. (1855). Some account of the marine botany of the colony of western Australia. *Transactions of the Royal Irish Academy* 22: 525–566.

Huanel, O.R., Nelson, W.A., Robitzch, V., Mauger, S., Faugeron, S., Preuss, M., Zuccarello, G.C., & Guillemin, M-L. (2020). Comparative phylogeography of two *Agarophyton* species in the New Zealand archipelago. *Journal of Phycology* 56: 1575–1590.

Lyra, D. de M., Iha, C., Grassa, C.J., Cai, L., Zhang, H.G., Lane, C., Blouin, N., Oliveira, M.C., Nunes, J. M de C. & Davis, C.C. (2021). Phylogenomics, divergence time estimation and trait evolution provide a new look into the Gracilariales (Rhodophyta). *Molecular Phylogenetics and Evolution* 165(107294): [1–14].

May, V. (1948). The algal genus *Gracilaria* in Australia. *Bulletin of the Commonwealth of Australia Council for Scientific and Industrial Research* 235: 1–64.

Minh, B.Q., Schmidt, H.A., Chernomor, O., Schrempf, D., Woodhams, M.D., von Haeseler, A. & Lanfear, R. (2020). IQ-TREE 2: new models and efficient methods for phylogenetic inference in the genomic era. *Molecular Biology and Evolution* 37: 1530–1534.

Nelson, W.A. (1987). The New Zealand species of *Gracilaria* Greville (Rhodophyta, Gigartinales). *New Zealand Journal of Botany* 25: 87–98.

Preuss, M., Muangmai, N., Nelson, W.A., Guillemin, M.-L., West, J.A. & Zuccarello G.C. (2020). *Agarophyton transtasmanicum* sp. nov. from Australia and New Zealand. *Phycologia* 59(3): 238–245.

Royce, R.D. (1955). Algae of the Swan River. *In*: Swan River Reference Committee, report by sub-committee on Pollution of Swan River. Government Printer, Perth.

Thomson, J.M. (1946). The fauna of the algal zone of the Swan River Estuary. A preliminary survey of Freshwater Bay with notes on the chief species. *Journal of the Royal Society of Western Australia* 30: 55–73.

Withell, A.F., Millar, A.J.K. & Kraft, G.T. (1994). Taxonomic studies of the genus *Gracilaria* (Gracilariales, Rhodophyta) from Australia. *Australian Systematic Botany* 7: 281–352.

Womersley, H.B.S. (1996). *The marine benthic flora of southern Australia - Part IIIB - Gracilariales, Rhodymeniales, Corallinales and Bonnemaisoniales*. (Australian Biological Resources Study with assistance from the State Herbarium of South Australia: Canberra & Adelaide.)

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dbca.wa.gov.au/nuytsia/ *Nuytsia* 34: 227–254
https://doi.org/10.58828/nuy01061 Published online 26 October 2023

Revision of the connate bract group allied to *Goodenia panduriformis* (Goodeniaceae), including recognition of three new species

Kelly A. Shepherd[1] & Brendan J. Lepschi[2]

[1]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2]Australian National Herbarium, Centre for Australian National Biodiversity Research,
GPO Box 1700, Canberra, Australian Capital Territory, 2601
[1]Corresponding author, email: kelly.shepherd@dbca.wa.gov.au

Abstract

Shepherd, K.A. & Lepschi, B.J. Revision of the connate bract group allied to *Goodenia panduriformis* (Goodeniaceae), including recognition of three new species. *Nuytsia* 34: 227–254 (2023). The taxonomy of several species of *Goodenia* with connate bracts allied to *G. panduriformis* (A.Cunn. ex Benth.) K.A.Sheph. was evaluated through morphological assessment of herbarium specimens. Consequently, the circumscriptions of *G. connata* (F.Muell.) K.A.Sheph., *G. discophora* (F.Muell.) K.A.Sheph., *G. daviesii* (F.Muell.) K.A.Sheph. and *G. panduriformis* are revised and new descriptions provided. Three new species, *G. aluta* K.A.Sheph. & Lepschi, *G. crescentiloba* K.A.Sheph. & Lepschi and *G. obscurata* K.A.Sheph. & Lepschi are also recognised, the latter being listed as a species of conservation concern. Further, a replacement lectotype for *Velleia helmsii* K.Krause is designated and a key, distribution maps and figures are included.

Introduction

Following the recent recircumscription of *Goodenia* Sm. to include *Velleia* Sm., *Verreauxia* Benth., *Selliera* Cav. and *Pentaptilon* E.Pritz. (Shepherd *et al.* 2020), a curation effort was undertaken in select Australian herbaria to redetermine specimens of the subsumed taxa. During this process it became apparent that there were novel taxonomic entities within a group from subg. *Monochila* sect. *Velleia* (Sm.) K.A.Sheph. (*sensu* Shepherd *et al.* 2020) allied to *G. panduriformis* (A.Cunn. ex Benth.) K.A.Sheph. This group, comprising *G. panduriformis*, *G. connata* (F.Muell.) K.A.Sheph., *G. discophora* (F.Muell.) K.A.Sheph. and *G. daviesii* (F.Muell.) K.A.Sheph., form a well-supported monophyletic subclade within 'Goodenia Clade C' based on a combined phylogeny of nrDNA + cpDNA sequence data (see Figure 8, Shepherd *et al.* 2020). With the exception of *G. daviesii*, members of this subclade have bracts that are fused to form a distinctive disc or funnel (Figure 1). While *G. daviesii* has free bracts, it is morphologically similar to *G. connata* in other respects. Moreover, bracts subtending some terminal flowers in *G. connata* may be free rather than fused (see under that species for further discussion). Representatives of this group are distributed across mainland Australia, including the arid interior. They are short-lived perennials and disturbance opportunists, frequently appearing post-fire or in disturbed habitats. Some are also poisonous to livestock (Watson 1946; Gardner & Bennetts 1955) and the common name of two species alludes to

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

this, as *G. discophora* is sometimes referred to as Cabbage Poison, while *G. panduriformis* is called Pindan Poison. The toxicity is likely due to the presence of a glucoside called 'vellein', named for *V. discophora* F.Muell. (= *G. discophora*), the species from which this compound was first isolated (Bottomley & White 1951).

A significant number of herbarium collections have been made since Roger Carolin's seminal works on *Velleia* (Carolin 1967a, 1992) and, with this increase in material, it has become apparent there is more taxonomic diversity within the *G. panduriformis* group than previously recognised. Our systematic study has revealed diagnostically informative variation in a range of vegetative and floral features, including the size, shape and degree of fusion of the sepals, the size, colour and presence of wing tissue on the corolla lobes, the indumentum on the style, and ovule number. Consequently, we have recircumscribed *G. panduriformis*, *G. connata*, *G. discophora*, and *G. daviesii*, and recognised three new taxa. *Goodenia crescentiloba* K.A.Sheph. & Lepschi, a widespread species found across the arid regions of northern Australia, is shown to be distinct from *G. panduriformis*, which is now largely confined to the Kimberley region of Western Australia. *Goodenia aluta* K.A.Sheph. & Lepschi is recognised from central and Western Australia and is distinct from typical *G. connata* on account of its yellow flowers and usually glabrous style. Finally, *G. obscurata* K.A.Sheph. & Lepschi, a white-flowered species with a yellow throat from the western Pilbara of Western Australia, is distinguished from the yellow-flowered *G. discophora*, which is confined to more southern localities in the Eremaean and South-West provinces of Western Australia.

The discovery of three undescribed, distinctive and conspicuous taxa within an equally distinctive and visible component of the Australian flora (the Goodeniaceae), may seem surprising. However, it may be that their very conspicuousness has led to them being overlooked by previous workers and collectors. Anecdotal evidence suggests that the obvious connate bracts found in this group of taxa has led botanists to uncritically place material in one of the previously recognised taxa without further consideration, including in the botanically well-surveyed Pilbara region where *G. aluta*, *G. obscurata* and *G. connata* all occur. However, we note that *G. aluta* has been informally recognised in the southern Northern Territory by botanists familiar with the flora of that region, where it co-occurs with *G. connata* (D.E. Albrecht pers. comm.). Specimens of the yellow- to orange-yellow-flowered *G. crescentiloba*, a taxon morphologically more similar to *G. panduriformis*, have been frequently referred to *G. connata* by collectors and herbarium workers alike. This is possibly because the morphology of these specimens does not match *G. panduriformis s. str.* and so they were placed in *G. connata* by default. This has resulted in a confused and heterogeneous concept of *G. connata* that has been further compounded by the inclusion of specimens of both the yellow-flowered *G. aluta* and the white-flowered *G. obscurata*.

Even with the recognition of three new taxa, some taxonomic uncertainty remains in this group with respect to the morphological variation exhibited by *G. connata s. str.*, the relationship between *G. daviesii* and *G. connata*, and the distinctiveness or otherwise of *Velleia helmsii* K.Krause, a name previously applied to hairy plants of *G. connata* by some workers (*in sched.*) but considered synonymous with that species by Carolin (1967a, 1992) and herein. Resolution of these taxonomic issues is not possible on the basis of existing collections and data: fieldwork throughout the ranges of *G. daviesii* and *G. connata* is required, preferably supported by molecular data.

Methods

This study was based on the examination of herbarium specimens held at AD, BRI, CANB, DNA, MEL, NSW, NT, and PERTH. Supplementary material including types were viewed online via JSTOR

Global Plants (https://plants.jstor.org/) or the Museum National d'Histoire Naturelle (P) database (https://science.mnhn.fr/institution/mnhn/search). Measurements were coded from dried herbarium specimens, with floral characters scored from material that was rehydrated in boiling water and a drop of detergent. The width of the style was measured at the widest point, while sepal length and width were recorded from flowering material only. Measurements of seed length and width refer to the seed only, excluding the seed wing. Seed wing measurements were recorded at the widest point of that structure.

Distribution maps include specimens observed in the herbaria listed above, with decimal latitude and longitude data downloaded from Florabase (Western Australian Herbarium 1998–) and The Australasian Virtual Herbarium (https://avh.chah.org.au/). Maps were created using QGIS version 2.18.16 and include version 7 of the Interim Biogeographic Regionalisation for Australia (IBRA) bioregions (Australian Government Department of Agriculture, Water and the Environment 2012).

Leaves and inflorescence structure

Many of the specimens available for study are incomplete, lacking the lower portion of the plant including the basal leaves (particularly in the larger and more robust species *G. connata*, *G. crescentiloba*, and *G. panduriformis*). In those specimens where these features are present, there appears to be considerable variation in leaf shape, the degree of dissection of the margins, and glaucousness; however, it is unclear whether this variation is of taxonomic significance. Further field sampling from across the range of each species within this clade would help clarify the potential diagnostic value of these features.

The inflorescence structure in *Goodenia* was described by Carolin (1967b) at its simplest, as an open, polytelic, thyrsoid form where the bracts are leaf-like or reduced. Inflorescence structure is more complicated in sect. *Velleia*, as the above ground enrichment zone is contracted, so the leaves appear basal and most of the plant habit is represented by a series of elongated 'dichotomous axillary cymes' (Carolin 1967a), characterised as 'Form H' in Shepherd *et al.* (2020). Because of this complicated structure, we record the peduncle length as encompassing the whole inflorescence, which effectively is equivalent to the height of the plant.

The total number of flowers in the terminal dichasia (Figure 1) are diagnostic for species in this group. *Goodenia panduriformis* in particular is distinctive, as the lateral branches of each dichasium grow more strongly than the others in the inflorescence, resulting in the superficial appearance of a 'raceme of clusters' (Carolin 1967a) of up to 24 flowers.

The structure of bracteoles in *Goodenia*, if present, is also complicated. Albrecht (2002) observed that axillary buds sometimes subtend flowers (e.g. in *G. halophila* Albr. and *G. cylindrocarpa* Albr.), suggesting they are perhaps better referred to as 'opposite or sub-opposite bracts' following the concepts of Briggs and Johnson (1979). The bracts and bracteoles in the *G. panduriformis* clade form distinctive, disk-like structures around the stem, which may or may not be completely fused (and are completely free in *G. daviesii*); however, it is difficult to pinpoint the exact transition from bracts to bracteoles due to the complicated structure of the inflorescence. For practical reasons, we have decided to not to attempt to distinguish between these structures and refer to all prophylls as bracts. The length of the pedicel is measured from the subtending bract to the terminal flower (Figure 1).

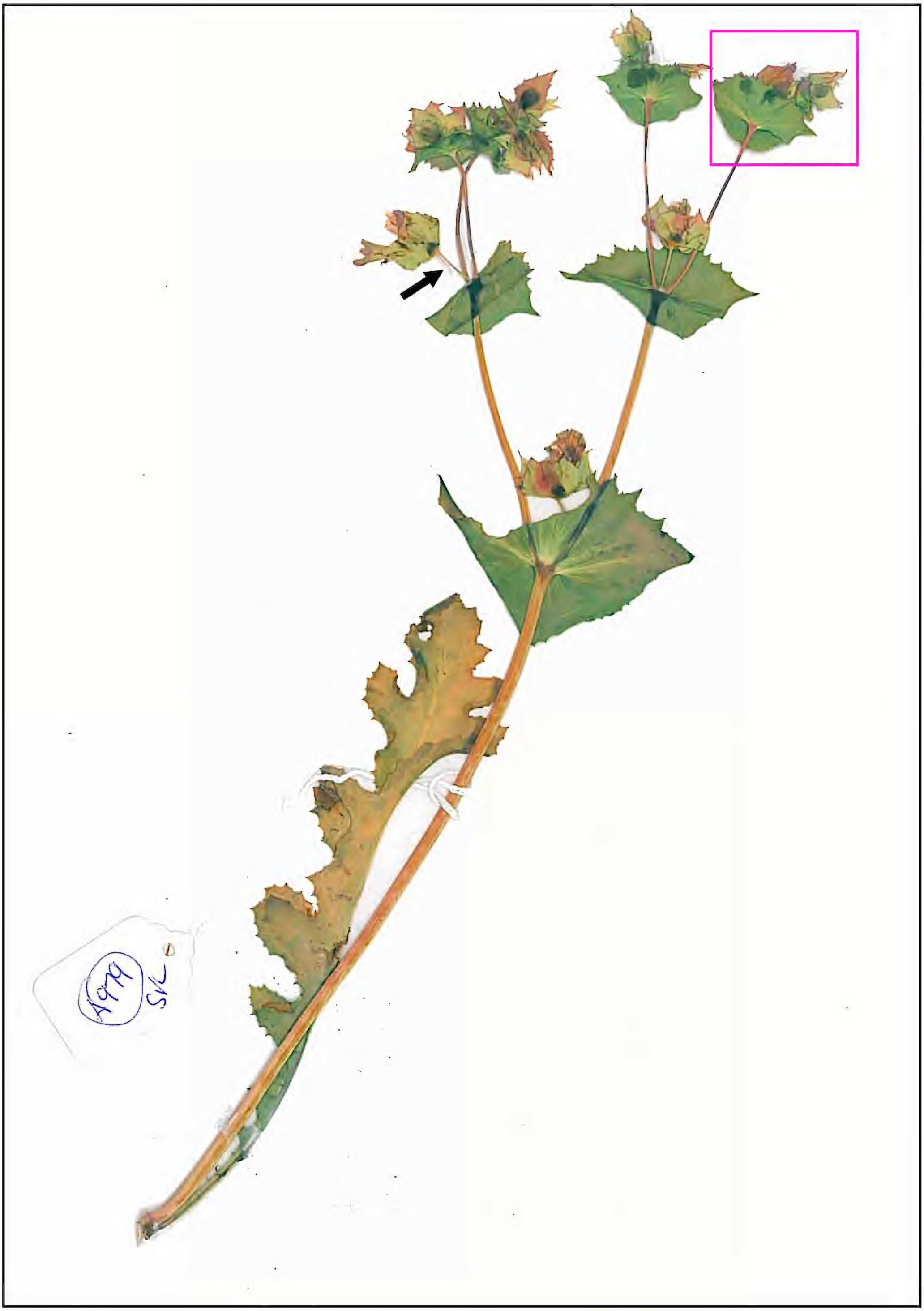

Figure 1. *Goodenia connata* herbarium specimen highlighting the pedicel (black arrow) and one of the terminal dichasia (purple square) as measured in the descriptions. Voucher: *S.L. van Leeuwen* 4979 (PERTH 06765378).

Taxonomy

Key to the connate bract group allied to *Goodenia panduriformis*

1. Bracts free, paired, margins dentate to denticulate; peduncles with scattered to dense hairs 0.2–0.6 mm long (WA: Meekathara–Balladonia).. **G. daviesii**

1: Bracts usually connate into a funnel or disc (may be split on one side or rarely free and paired in some terminal flowers), margins entire to dentate; peduncles glabrous or with moderately dense hairs 0.1–0.3 mm long basally **2**

  2. Robust herb 1–1.5 m high; inflorescence with terminal clusters of (7–)10–24 flowers; connate bracts usually split almost to base on one side; sepals free (or almost so); corolla 25–29 mm long (WA: Kimberley) .... **G. panduriformis**

  2: Herb 0.15–1 m high; inflorescence a terminal dichasium of 1–7 flowers; connate bracts rarely split on one side; sepals fused at the base in a tube 1–5.5 mm long; corolla 14–29 mm long **3**

    3. Style usually glabrous, rarely with scattered hairs 0.1–0.5 mm long; apex of posterior sepal rounded with an apiculus, margin entire; corolla yellow with brownish or purplish brown markings; abaxial corolla lobe wings obsolete or rarely very narrow, 0.2–0.3 mm wide (WA: Wittenoom–Gibson Desert; NT; SA) .... **G. aluta**

    3: Style with scattered to dense hairs 0.2–2 mm long; apex of posterior sepal acute to acuminate, margin entire to dentate; corolla yellow, orange yellow, cream, white, whitish green to pale violet, very pale pink, pinkish mauve or yellowish pink; abaxial corolla lobe wings 0.3–3.2 mm wide, rarely obsolete **4**

      4. Posterior sepal 16.5–25 mm long; margin of bracts crescentic to shallowly crescentic dentate; corolla 22–29 mm long, yellow to orange-yellow (WA, NT: Little Sandy Desert–Tanami) .... **G. crescentiloba**

      4: Posterior sepal 5.5–15 mm long; margin of bracts entire to dentate; corolla 14–25 mm long, cream, white, whitish green to pale violet, very pale pink, pinkish mauve, yellowish pink or yellow **5**

        5. Sepals connate into a tube 1.5–2.2 mm long, posterior sepal narrowly ovate, 1.4–5.5 mm wide; corolla yellow with deep orange throat (WA: S of Shark Bay–N of Esperance) .... **G. discophora**

        5: Sepals connate into a tube 2.3–5.5 mm long, posterior sepal ovate, 6.2–12.3 mm wide; cream, white, whitish green to pale violet, very pale pink, pinkish mauve or yellowish pink **6**

          6. Corolla white or very pale pink with a yellow throat, 14–19 mm long; sepals glabrous, entire, fused at the base 2.3–3.8 mm, posterior sepal ovate, free portion 5.5–7.5 mm long, 6.2–7 mm wide; ovules 11–16 (WA: W Pilbara from W of Fortescue to Karijini NP) .... **G. obscurata**

          6: Corolla cream, white, whitish green to pale violet, pinkish mauve or yellowish pink, 16–25 mm long; sepals glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long, entire to dentate, fused at the base 4.5–5.3 mm, posterior sepal broadly ovate, free portion 7.5–8.5 mm long, 8.4–10.5 mm wide; ovules (20–)28–40 (WA, SA, Qld, NSW, Vic) .... **G. connata**

Goodenia aluta K.A.Sheph. & Lepschi, *sp. nov.*

Type: 60.6 km (by air) N of Kiwirrkurra, Western Australia, 10 September 2015, *P.C. Jobson & R. Davis* J 12078 (*holo*: PERTH 09088830!; *iso*: CANB 834240!; NT D0269563!).

[*Velleia connata auct. non* F.Muell.: R. Carolin, *Proc. Linn. Soc. New South Wales* 92: 36–38 (1967), *p.p.*; R.C. Carolin in J.P. Jessop (ed.), *Fl. Centr. Australia* 352 (1981), *p.p.*; R.C. Carolin in A.S. George (ed.). *Fl. Australia* 35: 287–288 (1992), *p.p.*]

Annual or short-lived perennial *herb*, (0.15–)0.5–0.6 m high. *Leaves* arranged in a basal rosette, obovate, denticulate, petiolate, lamina (including petiole) 37–68 mm long, 15–23 mm wide, glabrous, with a densely hairy axil, apex rounded with a short apiculus, base attenuate. *Inflorescence* an elongated, branched dichasium, with terminal dichasia of 1 or 2 flowers; peduncles 500–600 mm long including inflorescence, glabrous; pedicels 8–19 mm long, glabrous; bracts connate into a disk, not slit to the base, 15–52(–71) mm diam., glabrous, with a densely hairy axil, apex rounded with an apiculus, margin entire or with very shallow, scattered teeth. *Sepals* 5, basally fused for 4.5–5.3 mm, glabrous on both surfaces, apex rounded with an apiculus, margin entire; posterior sepal larger than the remainder, broadly ovate, free portion 7.5–8.5 mm long, 8.4–10.5 mm wide, remainder ovate, 6.2–8.5 mm long, 7–8.1 mm wide. *Corolla* 16–20 mm long, yellow with brownish or purplish brown markings, with a short pouch, glabrous on the outer surface, inner surface with scattered to moderately dense hairs 0.2–0.3 mm long in throat and faint enations; tube 2–3 mm long. *Adaxial corolla lobes* falcate-oblong, 7–10.7 mm long, 2–2.5(–3.5) mm wide, basally fused for a further 3–4 mm; auricle 4.5–5.7(–9.5) mm long, 2–3.5 mm wide, with dense hairs 0.4–0.7 mm long on the inner margin; wing above auricle 1.2–2.7 mm long, 0.8–2 mm wide, inner surface with dense hairs, wing opposite auricle obsolete. *Abaxial corolla lobes* oblong, 4–5.6 mm long, 3.1–3.5 mm wide, basally fused for a further 6.6–9 mm, wing obsolete or rarely very narrow and 2.4–3 mm long, 0.2–0.3 mm wide, not exceeding the length of the lobe. *Stamens* 5, filaments 3.7–5 mm long, 0.3–0.7 mm wide; anthers linear, 2.6–3.3 mm long, 0.8–1.2 mm wide. *Style* 7–8.2 mm long, 1.3–1.5 mm wide, usually glabrous; indusium obovoid, slightly curved inwards, 2.2–2.8 mm long, 4–5 mm wide, abaxial surface glabrous or with scattered hairs 0.1–0.5 mm long, adaxial surface with scattered to moderately dense hairs 0.3–0.5 mm long, upper lip with dense bristles 0.9–1 mm long, lower lip glabrous with bristles 0.4–0.6 mm towards the edges and 0.1 mm long at the centre. *Ovary* elliptic, 2.5–2.9(–3.5) mm long, 2.9–3 mm wide, glabrous, septum obsolete, with (20–)25–30 ovules. *Fruit* a capsule, ovoid, glabrous, *c.* 12 mm long, *c.* 14 mm wide. *Seeds* ovate, flat, brown, 3.6–4.5 mm long, 2.7–3.5 mm wide, with small projections over the surface; wing golden brown, not overlapping seed margin, 1.8–2.3(–2.7) mm wide. (Figure 2)

Diagnostic features. Readily distinguished from allied species by the following features: bracts connate into a disk, not slit to the base, glabrous, apex rounded with an apiculus, margins entire or with very shallow, scattered teeth; terminal dichasia of 1 or 2 flowers; a yellow corolla 16–20 mm long with brownish or purplish brown markings; pedicels glabrous; sepals fused at the base for 4.5–5.3 mm, glabrous, rounded with an apiculus and entire margins, posterior sepal 7.5–8.5 mm long, 8.4–10.5 mm wide; abaxial corolla wings obsolete or very narrow (0.2–0.3 mm wide), not exceeding the length of the lobe; style 7–8.2 mm long, glabrous; and (20–)25–30 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: Kiwirrkurra Indigenous Protected Area; 18.3 km by track E of Kiwirrkurra store, along track to Balgo, 12 Sep. 2015, *D.E. Albrecht* DEA 14436 *& R. Butcher, P.C. Jobson, R. Davis* (CANB 887405, NT D0275109 *n.v.*, PERTH 09509445); Eagle Bore Study Site, 16 July 2001, *T.B. Bragg* 2001-8 (MEL 2289271, OMA *n.v.*, PERTH 05663148); Hamersley Range to Marillana Stn, 7 May 1958, *N.T. Burbidge* 6015 (CANB 53757, PERTH 02763583);

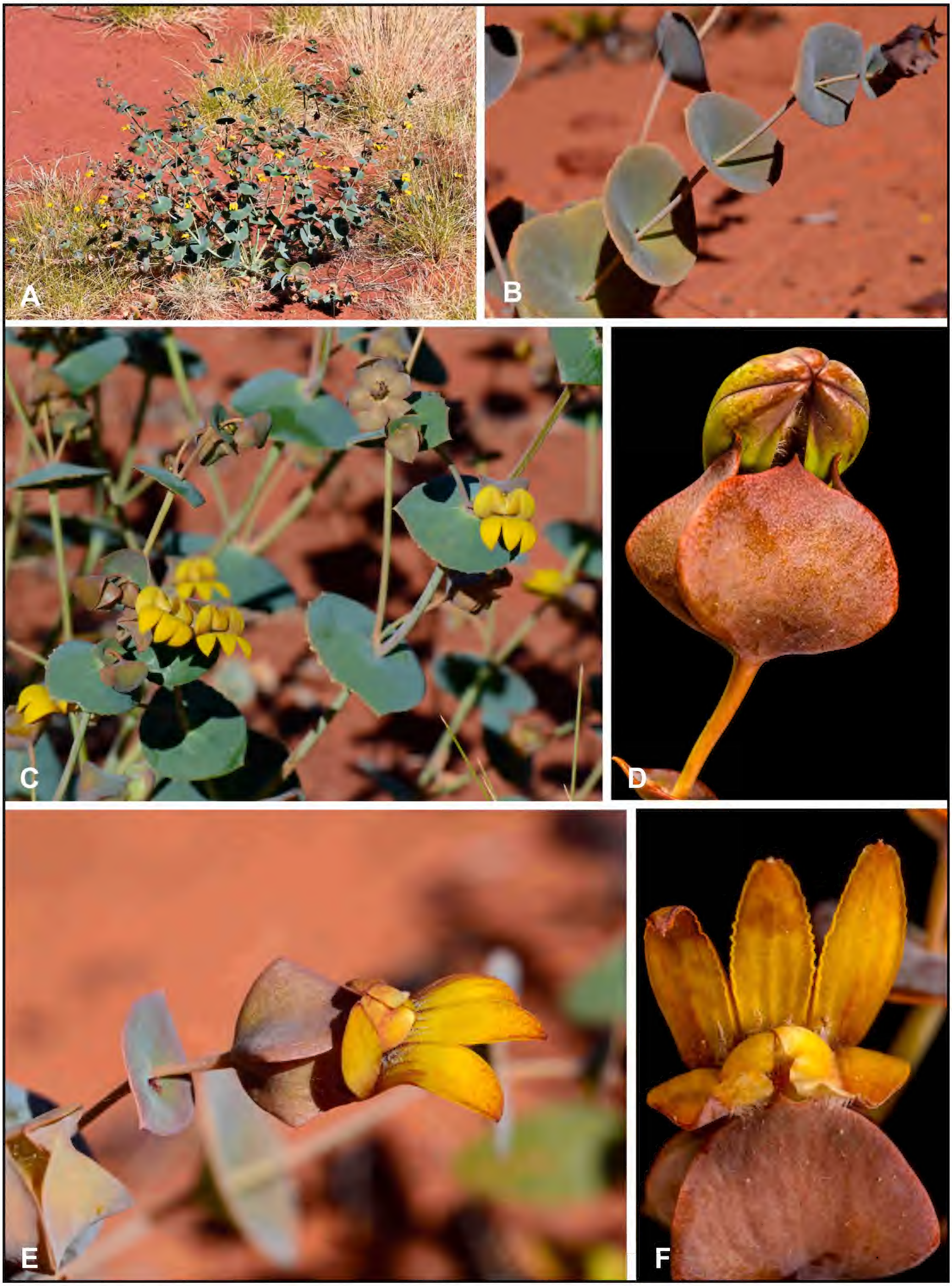

Figure 2. *Goodenia aluta*. A – habit; B – young inflorescence showing the connate disk-like bracts; C – flowering stems; D – young bud showing the very broad posterior sepal with an apiculate apex and entire margins; E – side view of flower highlighting the basally fused sepals and short adaxial corolla lobes with an obsolete wing on the outer margin; F – flower from above showing the almost obsolete wings on the abaxial corolla lobes. Vouchers: *M. Goods* DD 1497 (PERTH 09124330) (A, C); *G. Goods* DD468 (B, E); Kiwirrkurra, WA, 2015 (unvouchered) (D, F). Images: M. Goods (A, C), G. Goods (B, E), R. Whyte (D, F).

Patience Well, Gibson Desert, 1 Mar. 2001, *C.P. Campbell* 1154 (CANB 06335802, PERTH 06335802); 50 km NW of Maruwa, 28 July 2016, *M. Goods* DD 1137 (PERTH 08898693); Hamersley Stn, 1 Aug. 1995, *J. Shaw* 02 (PERTH 04268490), Little Sandy Desert, 23 km N of Cooma Well along the No. 1 Vermin Proof Fence (Original fence), 31.3 km E of Old Cundlebar, 13.4 km SSE of Burranbar Pool on Savory Creek, 10.2 km SW of Savory Well on Savory Creek, 14. Aug. 2001, *S. van Leeuwen* 4884 (CANB 570481, MEL 2425487, PERTH 06473067).

NORTHERN TERRITORY: 24.5 km N of Barrow Creek along the Stuart Hwy, 13 Sep. 1983, *L.A. Craven* 8198 (CANB 398951, MEL 0715595, NT D0073796 *n.v.*); 89 miles [143 km] from Yuendumu towards Rabbit Flat, July 1971, *C.H. Gittins* 2265 (BRI AQ 0000355 *n.v.*, CANB 745659, NSW 2400721); 15 km SSE Sangsters Bore, Tanami Desert, 10 July 1983, *P.K. Latz* 13220 (MEL 0725617, NT A0089563); 25 km East of NE corner Lake Mackay, 4 Oct. 2001, *P.K. Latz* 18132 (MEL 2289275, NT A0107307); 18 miles [28.9 km] NE of Barrow Creek Township, 24 Aug. 1956, *M. Lazarides* 5823 (AD 95918102, BRI AQ0225608, CANB 109403, MEL 0009623, NE 14481 *n.v.*, NSW 5612, NT A0082967, PERTH 02763486).

Phenology. Flowering specimens collected in March and from May to October. Fruiting specimens collected from May to October.

Distribution and habitat. *Goodenia aluta* is distributed from the Pilbara region in Western Australia eastwards to the Northern Territory, occurring in the Gascoyne, Great Sandy Desert, Little Sandy Desert, Gibson Desert and Tanami bioregions. It also occurs on the margins of the Central Ranges, Davenport Murchison Ranges and Burt Plain bioregions (Figure 3). It is found on red sandy gravel over sandstone, sandplains between dunes or rarely on lateritic plains, and is associated with low mallee or *Acacia* shrublands over *Triodia*.

Conservation status. This species is widespread across arid Western Australia and the Northern Territory and is not considered to be under threat.

Etymology. From the Latin *aluta* (purse or pouch made of soft leather), in reference to the appearance and texture of the distinctly broad sepals that are fused at the base.

Affinities. *Goodenia aluta* is superficially similar to *G. connata* but is readily distinguished by its sepals, which are entire (vs entire to dentate) and have a rounded apex with an apiculus (vs acuminate). The corolla in *G. aluta* is yellow with brownish or purplish brown markings (vs cream, white, whitish green, pale violet, pinkish mauve or yellowish pink), and the abaxial corolla lobe wings are usually obsolete or rarely 2.4–3 mm long and 0.2–0.3 mm wide (vs 1.5–6 mm long and 0.4–2 mm wide, or rarely obsolete in some plants from western Queensland). It also has a style that is usually glabrous, or more rarely with a few scattered hairs (vs scattered hairs).

Notes. Three Western Australian collections of *G. aluta* from east of Newman and in the Little Sandy Desert (*R.D. Royce* 1655 (PERTH 02763826); *G.J. Morse* 209 (CBG 8504000, PERTH 02763680); *Desert Dreaming Expedition* 78 (PERTH 03170012)) have a few scattered hairs on the style rather than being glabrous as observed in all other specimens. These specimens have yellow flowers and obsolete wings on the abaxial corolla lobes and in all other respects appear to be a match for typical *G. aluta*. Specimens of *G. connata* from Ethabuka Station (Bush Heritage reserve) in western Queensland (*N.G. Walsh* 7163 *& J. Silcock* (MEL 2346274, MEL 2342259)), which also have obsolete wings on the abaxial corolla lobes (Figure 4F [right hand flower]), have denser hairs on the style and the flowers are pale yellowish pink, and are referred to *G. connata*.

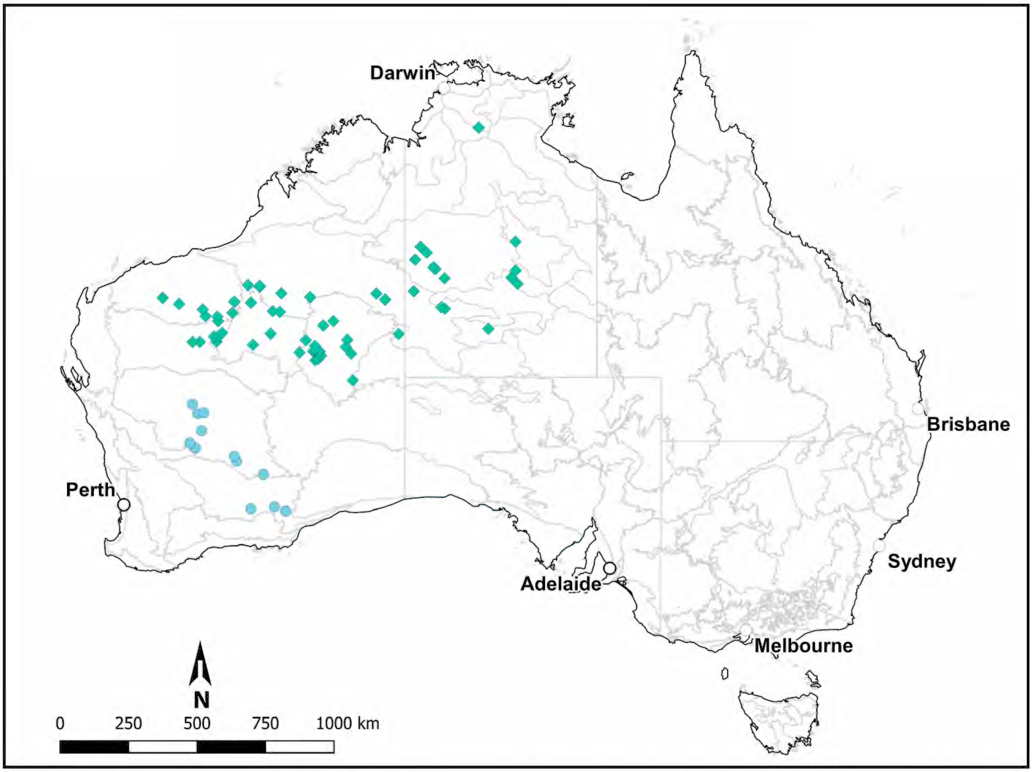

Figure 3. Distribution of *Goodenia aluta* (◆) and *G. daviesii* (●) with IBRA subregions (Australian Government Department of Agriculture, Water and the Environment 2012) in pale grey.

Goodenia connata (F.Muell.) K.A.Sheph., *Phytokeys* 152: 88 (2020). *Velleia connata* F.Muell., *Trans. Philos. Soc. Victoria* 1: 18 (1855). *Type*: Sandhills towards the junction of the Murray & Murrumbidgee [New South Wales/Victoria], December 1853, *F. von Mueller s.n.* (*holo*: MEL 594385!).

Velleia helmsii K.Krause in H.G.A. Engler, *Das Pflanzenreich IV* 54 (277): 33, 35 (1912). *Type citation*: 'Eremaea: Victoria Wüste, Camp 53, unter 29° 20 s. Br. Und 124° 50 ö. L. (Helms – blühend im September 1891 – Herb. Kew, Berlin, Sydney).' *Type*: Victoria desert, Camp 53 [Western Australia], 15 September 1891, *R. Helms s.n.* (*lecto*, inadvertently designated by R.C. Carolin, *Proc. Linn. Soc. New South Wales* 92(1): 37 (1967): B, destroyed; *isolecto*: K, MEL 9628, NSW 75658; replacement *lecto*, here designated: MEL 9628!; *isolecto*: AD 96620116 *n.v.*, AD 207923A *n.v.*, K 000215452 image!, NSW 75658!, NSW 82670!, NSW 2400727!).

Annual or short-lived perennial *herb*, 0.15–0.5 m high. *Leaves* in a basal rosette, obovate to spathulate, entire or denticulate to lyrate, petiolate, lamina (including petiole) 42–325 mm long, 10–85 mm wide, with lobes 2.5–42 mm long, 1–87 mm wide, glabrous or sometimes with scattered hairs 0.1–0.3 mm long on the margins, with a densely hairy axil, apex rounded to acute, base attenuate. *Inflorescence* an elongated, branched dichasium, with terminal dichasia of 2–5 flowers; peduncles 170–500 mm long including inflorescence, glabrous or with scattered hairs 0.1–0.3 mm long; pedicels 3–33 mm long, glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long; bracts connate into a disk (rarely leaf-like and paired towards apex), sometimes slit to the base, (6–)13–82(–110) mm diam., glabrous or with scattered hairs 0.1–0.5 mm long, with a densely hairy axil, apex acuminate to acute, margin entire to dentate. *Sepals* 5, basally fused for 2.5–5.5 mm, outer surface glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long, inner surface glabrous or with scattered to moderately dense hairs 0.1–0.3 mm long, apex acuminate, margin entire to dentate; posterior sepal larger than the remainder, broadly ovate, free portion 6–15 mm long, (5–)6.2–12.3 mm wide, remainder ovate to broadly ovate, 5.8–14.3 mm long, (3.5–)4.4–10 mm wide. *Corolla* 14–25 mm long, cream, white, whitish green to pale violet, pinkish mauve or yellowish pink, glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long on the outer surface towards the apex, inner surface with moderately dense to dense hairs 0.2–1.1 mm long in throat and at base and faint enations; tube 1–2.5 mm long. *Adaxial corolla lobes* falcate-oblong, 8–12.5 mm long, 1.8–3.4 mm wide, basally fused for a further 1.2–3.6 mm; auricle 4.7–7.3 mm long, 2–3.3 mm wide, with dense hairs 0.6–1.8 mm long on the inner margin; wing above auricle 2–4 mm long, 0.8–2.5 mm wide, wing opposite auricle 1.1–5.2 mm long, 0.3–2.2 mm wide. *Abaxial corolla lobes* oblong, 2.8–6.3 mm long, 1.1–4.1 mm wide, basally fused for a further 8.5–12 mm, wings 1.5–6 mm long, 0.4–2 mm wide (rarely obsolete in some plants from western Queensland), exceeding the length of the lobe by 0.2–1.4 mm. *Stamens* 5, filaments 2.9–4.3 mm long, 0.3–0.6 mm wide; anthers linear, 1.7–3.5 mm long, 0.4–1 mm wide. *Style* 5–6.2 mm long, 1.1–2.5 mm wide, with scattered to moderately dense hairs 0.3–1.8 mm long; indusium broadly obovoid, 2.2–3.2 mm long, 2.1–5.2 mm wide, abaxial surface with scattered hairs to moderately dense hairs 0.1–1.2 mm long, adaxial surface with scattered to moderately dense hairs 0.1–1.3 mm long, upper lip with dense bristles 0.5–1 mm long, lower lip glabrous or with bristles 0.1–0.7 mm long towards the edges. *Ovary* elliptic to obovate, 2.2–5.5 mm long, 2.1–6 mm wide, glabrous, septum with residual tissue, with (20–)28–40 ovules. *Fruit* a capsule, ovoid, glabrous, 8–13 mm long, 9–13 mm wide. *Seeds* ovate, flat, light brown, 3.2–3.8 mm long, 2.3–2.6 mm wide, smooth or with faint pits over the surface; wing golden brown, not overlapping seed margin, 1.3–2.1 mm wide. (Figure 4)

Diagnostic features. *Goodenia connata* is distinguished by the following combination of characters: bracts connate into a disk (rarely leaf-like and paired towards apex), sometimes slit to the base, glabrous or with scattered hairs 0.1–0.5 mm long, apex acuminate to acute, margin entire to dentate; terminal dichasia of 2–5 flowers with a cream, white, whitish green to pale violet, pinkish mauve or yellowish pink corolla 14–25 mm long; pedicels glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long; sepals fused at the base for 2.5–5.5 mm, glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long, apex acuminate with entire to dentate margins, posterior sepal 6–15 mm long, (5–)6.2–12.3 mm wide; abaxial corolla wings 1.5–6 mm long, 0.4–2 mm wide, exceeding the length of the lobe by 0.2–1.4 mm; style 5–6.2 mm long, with scattered hairs 0.3–1.8 mm long; and (20–) 28–40 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: *c.* 48 km from Roebourne turnoff to Wittenoom Rd in Gorge of Hammersley Range, 5 Aug. 1971, *A.M. Ashby* 4180 (AD 97418211 *n.v.*, NSW 2400725); 14 miles [22.5 km] NE of Wiluna, 15 Oct. 1947, *G.E. Brockway s.n.* (CANB 26688); 18.8 km W of turnoff to Eagle Rock Falls, on the Great Northern Hwy, 3 Sep. 2004, *R.J. Chinnock* 9713 (AD 170239 *n.v.*, DNA D0287427 *n.v.*, PERTH 07025181); *c.* 126 km N of Balladonia along Zanthus–Balladonia track, 23 Sep. 2003, *R. Davis* 10595 (PERTH 06537715); NE of Tjuntjuntjara, 26 Sep. 2011, *R. Davis & A. Pennington* RD 11928 (PERTH 08325936); Anne Beadell Hwy. 5.2 km W of Ilkurlka roadhouse. Great Victoria Desert, 6 Oct. 2010, *R. Davis, J. Jackson & D. Ferguson* 11635 (MEL 2360955, PERTH 08249016); Red sand plain, 94.9 km NE of homestead, Lake Mason Stn N of Sandstone, in Kaluwirri block, 18 Sep. 2005, *D.J. Edinger* 5489 (PERTH 07284527); W of Cundeelee Mission, 22 Sep. 1963, *A.S. George* 5902 (PERTH 02763699); Lorna Glen Stn, 10 km E of turnoff from Wiluna/Granite Peak Rd, 5 Sep. 2003, *K.F. Kenneally & D.J. Edinger* K 12509 E 3709 (PERTH 06705138); *c.* 124 km E of Balfour Downs HS on Talawanna Track, 9 April 1995, *A.A. Mitchell* PRP 89 (NSW 2400716, PERTH 04249631); Corvette Resources, Plumridge Project, NE

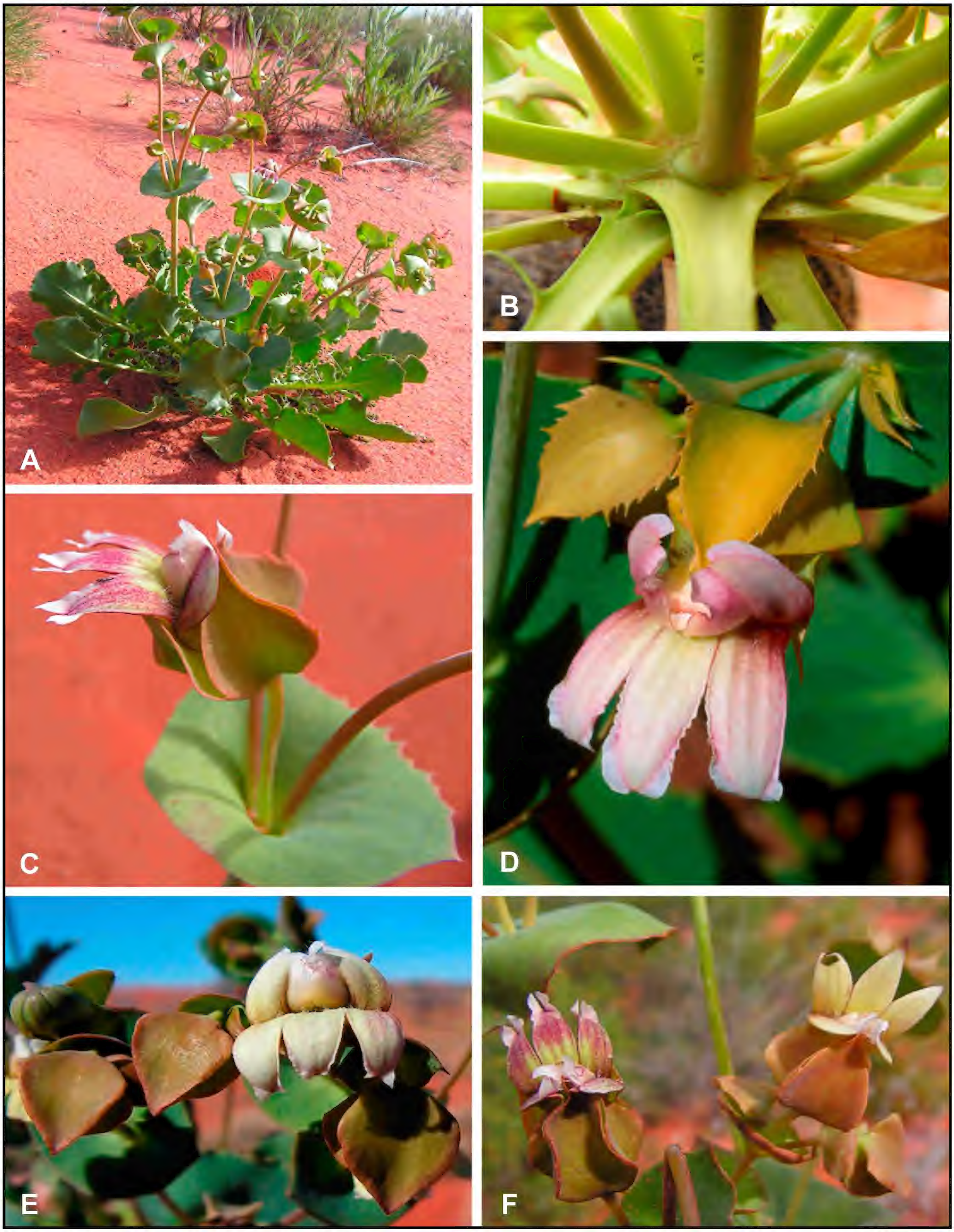

Figure 4. *Goodenia connata*. A – habit; B – glabrous petioles with dense hairs in the leaf axils; C – side view of flower showing connate bracts with the margin almost entire on one side and dentate on the other, and basally fused sepals; D – top view of flower showing dentate sepal margins and a pinkish corolla with obvious wing tissue on the apex of the lobes; E – flower with a yellowish pink corolla that has wing tissue on the lobes, and sepals with entire margins; F – two variable forms, one with a pinkish corolla with short wings on the abaxial lobes (left) and the other with a yellowish pink corolla with obsolete wings (right). Vouchers: Ethabuka Stn, Qld, 2010 (unvouchered) (A–C); *J.E. Wajon* 1169 (PERTH 07325436) (D); *C.J. Nicholson & R.W. Purdie* CJN415 (BRI AQ1004197) (E); *N.G. Walsh* 7163 *& J. Silcock* (MEL 2346274, 2342259) [right hand specimen, left unvouchered] (F). Images by: C.J. Nicholson (A–D, F); J.E. Wajon (E).

of the intersection of the PNC Baseline and Cable Haul Rd, 3 Sep. 2009, *S. Reiffer* SRe 103 (PERTH 08799695); 12 miles [19.3 km] NE of Millrose, Eremean Province, 8 Sep. 1958, *N.H. Speck* 1381 (CANB 109406, PERTH 02763605); 0.5 km N of Coondewanna Bore on track to Packsaddle, 6.8 km S of Packsaddle Hill, 19.9 km E of Mt Meharry, Hamersley Range, 10 Sep. 1991, *S. van Leeuwen* 973 (NSW 363564, PERTH 4003705); Little Sandy Desert, 9.4 km N of Lake Sunshine, 18 km SE of Yanneri Lake, 12.1 km SSW of Terminal Lake, 40.3 km ENE of Kulonoski East Well on Beyondie Stn, 35.2 km N of Bullen Hill, 18 Aug. 2001, *S. van Leeuwen* 4979 (CANB 570480, MEL 2425483, PERTH 06765378); 147 km SW of Warburton towards Laverton on Lasseter Hwy, 9 Apr. 1992, *F.A. Zich* 86 (CANB 433644, NSW 699640, PERTH 03590038).

NORTHERN TERRITORY: Serpentine Gorge, W of Alice Springs, 27 July 1967, *A.C. Beauglehole* ACB 24305 (AD 97533070, CANB 300716, MEL 0623272, NSW 2400723, PERTH 02763435); NW Simpson Desert, 27 Sep. 1972, *P.K. Latz* 4374 (AD 97508160 *n.v.*, CANB 298600, DNA A0049661 *n.v.*); 8 Mile Gap; 10 km E of Ellery Big Hole; West MacDonnell NP, 30 Aug. 2003, *P.K. Latz* 19155 (MEL 2283537, NT A0104567); Desert Grazing Block, 27 miles [43.4 km] NE of Narwietooma Stn, 15 Sep. 1956, *M. Lazarides* 5987 (AD 95918101 *n.v.*, BRI AQ0225607 *n.v.*, CANB 109404, CANB 109405, MEL 0009622, PERTH 02763478); Serpentine Gorge, 29 July 1967, *R. Maconochie* 447 (AD 97049445 *n.v.*, MEL 2193365); 34 miles [54.7 km] NW of Hamilton Downs, 23 Sep. 1955, *R.E. Winkworth* 1378 (MEL 0009629); Above E walls of Serpentine Gorge, 8 June 1974, *J.H. Willis s.n.* (MEL 2116559).

SOUTH AUSTRALIA: Lock, 5 Dec. 1967, *C.R. Alcock* 1697 (AD 98584737 *n.v.*, AD 96807200 *n.v.*, CANB 189836, NSW 88016, NSW 131637); About 38 km N of Cowell; about 3 km directly SE of Microwave Tower, 22 Oct. 1983, *J.D. Briggs* 1409 (AD 98722369 *n.v.*, CBG 8316106); *c.* 40 km NW of Ceduna, *c.* 2.5 km NW of Koonibba Hill, 4 Jan. 1979, *M.D. Crisp* 4764 (AD 98218446 *n.v.*, CBG 7900361); Billiatt CP – E side of main road, *c.* 13 km N of Park S boundary, 16 Nov. 2010, *D.J. Duval & D.E. Murfet* 2017 (AD 242832, K *n.v.*); Cooltong Conservation Park. NW boundary of Park along N-S fenceline track, 21 Oct. 2011, *D.J. Duval, J. White & L. Duffy* 2304 (AD 251542); 50 km N of Cowell on Lincoln Hwy, 3 Nov. 1992, *T. Hall* 443 (AD 99247245); 0.8 km direct NW of Buckleboo, Buckleboo Conservation Reserve (CR50), 20 Oct. 1998, *S.D. Kenny & V.C. Hagan* BS103-3881 (AD 117448); 41.7 km by road S of Pipalyatjara towards Kunytjanu, APY Lands, [9.5 km direct SSE of Ilarunga], 22 Oct. 1996, *P.J. Lang* BS23-26759 (AD 99837056); 11.9 km direct S of Mulyawara No. 1 Well, on Rodinia Track, 21 Sep. 2021, *P.J. Lang, P.D. Canty, J. Kellermann & R. Butcher* BS1137-199 (AD 281617, PERTH 09394281, PERTH 09394303); NW track, *c.* 2 km W of Corrobinnie Hill, off the southern boundary of Pinkawillinie Conservation Park, 15 Oct. 2007, *T.S. Te, D.J. Duval & M.J. Thorpe* 195 (AD 213887); Great Northern Hwy, 55.5 km W of Newman Drive, 31 July 2004, *J.E. Wajon* 1169 (MEL 2311650, PERTH 07325436); *c.* 24 km by road NW of Krewinkel Hill, *c.* 31 km by road SE of air strip at old Mt Davies Camp, on Pipalyatjara – Mt Lindsay Rd, 3 Sep. 1978, *J.Z. Weber* 5362 (AD 97838039 *n.v.*, MEL 0593590, NSW 663396 *n.v.*).

QUEENSLAND: 26.1 km W of St George, 28 Dec. 1998, *A.R. Bean* 14471 (BRI AQ0675280 *n.v.*, MEL 0291279); 0.5 km E of Calabah HS, *c.* 90 km SSE of Charleville, 16 Jan. 2008, *A.R. Bean & J. Wang* 27263 (BRI AQ0786309); 26.2 km from St George towards Bollon, 15 Oct. 1983, *E.M. Canning & B. Rimes* 5991 (BRI AQ0593241 *n.v.*, CBG 8312598, MEL 713686, NSW 66394); 12.7 km from Charleville toward Cunnamulla, by railway line, 19 Oct. 1983, *E.M. Canning & B. Rimes* 6058 (BRI AQ0593252 *n.v.*, CBG 8313271, MEL 0713686, MO *n.v.*, NSW 66393); 30 km W of St George on Barwon Hwy, 24 Sep. 2003, *R.A. Mckenzie* RAM03/174 (BRI AQ0762194); Ethabuka Stn (Bush Heritage reserve), 3 July 2015, *C.J. Nicholson & R.W. Purdie* CJN415 (BRI AQ1004197).

NEW SOUTH WALES: Shuttleton, Oct. 1903, *W. Baeuerlen* 3103 (AD 98831043, CANB 375797, MEL 0304119, PERTH 02763427); Just outside the S boundary of Mallee Cliffs NP, NNE of Euston off the Sturt Hwy, 10 Oct. 2000, *R.G. Coveny, G. Chapple, P.G. Kodela & H. McPherson* 18794 (AD 119106, CANB 549767, MEL 2067860, NSW 449196); H. Norris, Fairview [Fairview Park], [NE of] Burgooney, Nov. 1976, *G.M. Cunningham & P.L. Milthorpe s.n.* (CANB 827589); Griffith, 2 June 1934, *E.B. Farhy s.n.* (NSW 78493); Northern Boundary Track, 100 m W of Coombes Rd (which is in Scotia Sanctuary), Tarawi NR, 25 Nov. 2011, *R.L. Johnstone & G. Errington* 2991 (CANB 579151, MEL 2365597, NSW 888535); 2.5 miles [4 km] E of Euabalong turn-off along road from Lake Cargellico–Mt Hope, 23 May 1969, *P. Martensz* 179 (CANB 325355).

VICTORIA: 3 km ENE of Wonga Hut, Wyperfeld NP. Mallee Study area, 11 April 1977, *A.C. Beauglehole* ACB 55448 (MEL 541879); 8 miles [12.8 km] W of Annuello, 8 Oct. 1972, *A.C. Beauglehole & N. Macfarlane* ACB 40510 (MEL 520229); Murray–Sunset NP. Bambill South Track, 5.8 km S of Settlement Rd, 25 Nov. 2011, *J.L. Birch, N.G. Walsh, C.L. Gallagher & S. Stewart* 453 (MEL 2355909); Hattah–Kulkyne NP, on Murray Valley Hwy c. 5 km E of Hattah township, 12 Nov. 1998, *A.C. Cochrane, N.G. Walsh & R.J. Fletcher* 315 (MEL 2054401); Murray–Sunset National Park. Beside Nowingi Line Track about 10.1 km W of Meridian Rd, 23 Nov. 2010, *J.A. Jeanes & G. Lay* 2476 (CANB 579088, K *n.v.,* MEL 2338137, S *n.v.)*; Murray–Sunset NP. Nowingi Line Track, 100 metres E from Rocket Lake Track, 29 Oct. 2010, *V. Stajsic & J.A. Jeanes* 6181 (MEL 2359101); Nowingi, Oct. 1928, *H.B. Williamson s.n.* (MEL 9620, MEL 9621, MEL 9621, MEL 600905, MEL 600906).

Phenology. Flowers recorded in all months except February and May. Fruits recorded from March to November.

Distribution and habitat. This species is widespread in arid and semi-arid areas of all mainland states and territories (Figure 5). Found growing on stony slopes, ridges, outcrops and sandplains, on or between dunes, or near watercourses, in skeletal soil over granite or quartzite, or brown, orange, white or deep red sand, loam or fine clayey sand. Favours open *Eucalyptus* woodland or mallee, *Acacia* or *Melaleuca* shrubland and *Triodia* communities. Also recorded from open *Angophora* and *Callitris* woodland.

Conservation status. This widespread species is not currently considered to be under threat except in Victoria, where it is listed as Endangered (EN) (The State of Victoria Department of Environment, Land, Water and Planning 2023).

Affinities. See comments under *G. aluta*. *Goodenia connata* is also morphologically similar to *G. obscurata*. The latter differs in having a 14–19 mm long corolla that is white or very pale pink with a yellow throat (vs 14–25 mm and cream, white, whitish green to pale violet, pinkish mauve or yellowish pink), consistently glabrous and entire sepals (vs glabrous or with scattered to moderately dense hairs 0.1–0.5 mm long, and entire or dentate margins), posterior sepal 6.2–7 mm wide (vs (5–)6.2–12.3 mm), fewer ovules (11–16 vs (20–)28–40) and mostly longer seeds (3.6–4.4 mm long vs 3.2–3.8 mm).

Notes. This widespread taxon is morphologically variable. Leaves may be entire with shallowly dentate margins to lyrate and strongly dentate. There is also considerable variation in the presence and density of hairs and the dentation of the sepal margins. Many of the southern populations in Western Australia, and just across the border in South Australia, have hairs 0.1–0.5 mm long on the pedicels, bracts and sepals, with scattered to moderately dense hairs 0.1–0.4 mm long on the outer surface of the corolla; these specimens are a good match for the type of *Velleia helmsii*, a species

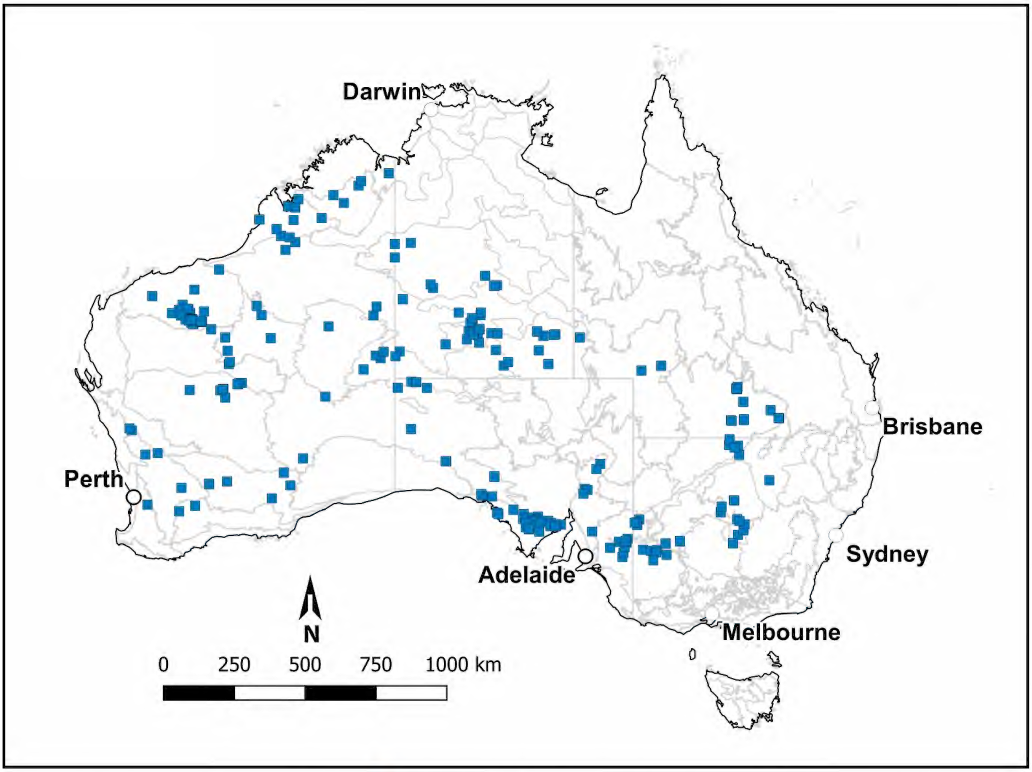

Figure 5. Distribution of *Goodenia connata* (■) with IBRA subregions (Australian Government Department of Agriculture, Water and the Environment 2012) in pale grey.

treated as a synonym of *G. connata* by Carolin (1967a, 1992). These characters appear to be somewhat continuous and both forms have been collected in apparent sympatry from near Cundeelee Mission in Western Australia (*A.S. George* 5902). Similarly, bract margins may be entire to strongly dentate, even on the same plant (Figure 2B). Flower colour is highly variable, as is the length of the wings on the abaxial corolla lobes, with variation apparent even within the same population. A population from far western Queensland (*N.G. Walsh* 7163 & *J. Silcock* (MEL 2346274, MEL 2342259)) that co-occurs with typical *G. connata* (Figure 4F) has a pale yellow corolla tinged with pink, residual to absent abaxial corolla wing tissue, and a hairy style. This population requires further investigation to determine whether taxonomic recognition of this variation is warranted. Finally, an unusual specimen from Western Australia (*A.M. Ashby* 4180 (AD 97418211 *n.v.*, NSW 2400725)), has slightly narrower sepals than is typical and an ovule number of 20 rather than 28–40. In other respects, this specimen is a match for material regarded as *G. connata*.

It is unclear if some of the morphological variation observed in *G. connata* is in any way influenced by environmental or phenological factors. Incomplete collections, particularly those lacking basal leaves, and inconsistent recording of corolla colour further impede investigation of this variation. This species would benefit from a morphological and molecular study that examines plants from across its range to determine if any of the observed variation warrants taxonomic recognition. *Goodenia daviesii* appears morphologically similar to the hairy forms of *G. connata* and therefore should be included in any taxonomic study of this complex.

Carolin (1967a) cited the type of the name *Velleia helmsii* K.Krause as '*Holotype* – Victoria desert, Camp 53. Helms (B. destroyed) – *Isotypes* (K. MEL 9628. NSW 75658).' This is here treated as effective lectotypification by Carolin on material formerly held at B. As Carolin's citation meets the relevant requirements of ICN Art. 7.11 (Turland *et al.* 2018), his use of the term 'holotype' is correctable under ICN Art. 9.10. As original material of this name held at B is no longer extant, having been destroyed during WWII, a replacement lectotype is designated here from among the remaining isolectotypes.

Goodenia crescentiloba K.A.Sheph. & Lepschi, *sp. nov.*

Type: 25 km east of north-east corner of Lake Mackay, Northern Territory, 4 October 2001, *P.K. Latz* 18123 (*holo*: PERTH 06750923!; *iso*: CANB 577333!, NT A0102635 *n.v.*).

[*Velleia panduriformis auct. non* A.Cunn. ex Benth.: R.C. Carolin in J.P. Jessop (ed.), *Fl. Centr. Australia* 352 (1981), *p.p.*; C.R. Dunlop, *Tech. Rep.: Conservation Commission N. Terr.* 26: 40 (1987).]

Annual or short-lived perennial *herb*, 0.5–1 m high. *Leaves* arranged in a basal rosette, obovate to narrowly obovate, dentate to lyrate, petiolate, lamina (including petiole) 53–170 mm long, 25–42 mm wide, with lobes 4–15 mm long, 5–20 mm wide, glabrous, with a densely hairy to floccose axil, apex acute, base attenuate. *Inflorescence* an elongated, branched dichasium, with terminal clusters of (1–)3–7 flowers; peduncles 500–1000 mm long including inflorescence, glabrous; pedicels 13–21 mm long, glabrous. *Bracts* connate into a disk, rarely slit nearly to the base and appearing paired, 5.3–89 mm diam., glabrous, with a densely hairy axil, apex acute to acuminate, margin with a crescentic to shallowly crescentic-shaped sinus between dentate lobes (or rarely entire). *Sepals* 5, basally fused for 3.5–8 mm, outer surface glabrous or with a few hairs only at the margin and towards apex of the sepals, inner surface glabrous, apex acute to acuminate, margin entire to shallowly dentate; posterior sepal larger than the remainder, broadly ovate to elliptic, free portion 16.5–25 mm long, 8.5–13.5 mm wide, remainder narrowly ovate to lanceolate, 10.5–20 mm long, 3.8–10 mm wide. *Corolla* 22–29 mm long, yellow to orange-yellow, glabrous on the outer surface, throat with scattered to moderately dense hairs 0.3–0.5 mm long and faint enations; tube 3.5–5.5 mm long. *Adaxial corolla lobes* falcate-oblong, 10–11.5 mm long, 3.5–4.2 mm wide, basally fused for a further 5–7 mm; auricle 7–8.5 mm long, 3–4.2 mm wide, with dense hairs 0.7–0.9 mm long on the inner margin; wing above auricle 2.4–3.5 mm long, 0.6–1.5 mm wide, with dense hairs, wing opposite auricle 2–3.3 mm long, 0.7–1.3 mm wide. *Abaxial corolla lobes* oblong, 3.9–5.5 mm long, 1–3.6 mm wide, basally fused for a further 10.3–12.6 mm, wing 1.7–3.8 mm long, 0.3–1.5 mm wide, not exceeding the length of the lobe. *Stamens* 5, filaments 4.5–7 mm long, 0.5–0.9 mm wide; anthers linear, 3.2–4.4 mm long, 0.6–1.9 mm wide. *Style* 8.3–10 mm long, 2.5–2.6 mm wide, with dense hairs 1–2 mm long towards the apex; indusium obovoid, sometimes slightly curved inwards, 2.7–4 mm long, 3.7–4.2 mm wide, abaxial surface glabrous or with scattered hairs 0.8–1 mm long, adaxial surface with scattered to moderately dense hairs 0.2–0.6 mm long, upper lip with dense bristles to 0.7–0.8 mm long, lower lip glabrous or with short bristles 0.1–0.4 mm long. *Ovary* elliptic, 3.8–4.5 mm long, 4.3–4.5 mm wide, glabrous, septum incomplete and less than one third length, with 13–18 ovules. *Fruit* a capsule, ovoid, glabrous, *c.* 12.5 mm long, *c.* 11 mm wide. *Seeds* subcircular to ovate, flat, golden brown, 5.5–6 mm long, 4.2–4.7 mm wide, smooth or punctulate with faint pits or projections towards the margin; wing golden brown, not overlapping seed margin, 2.5–3 mm wide, punctulate. (Figure 6)

Diagnostic features. Distinct within the genus by the following combination of characters: bracts connate into a disk (the latter rarely slit nearly to the base), glabrous, acute to acuminate, margins with a crescentic-shaped sinus between each dentate lobe (rarely entire); terminal clusters of (1–)3–7 flowers with a yellow to orange-yellow corolla 22–29 mm long; pedicels glabrous; sepals fused at

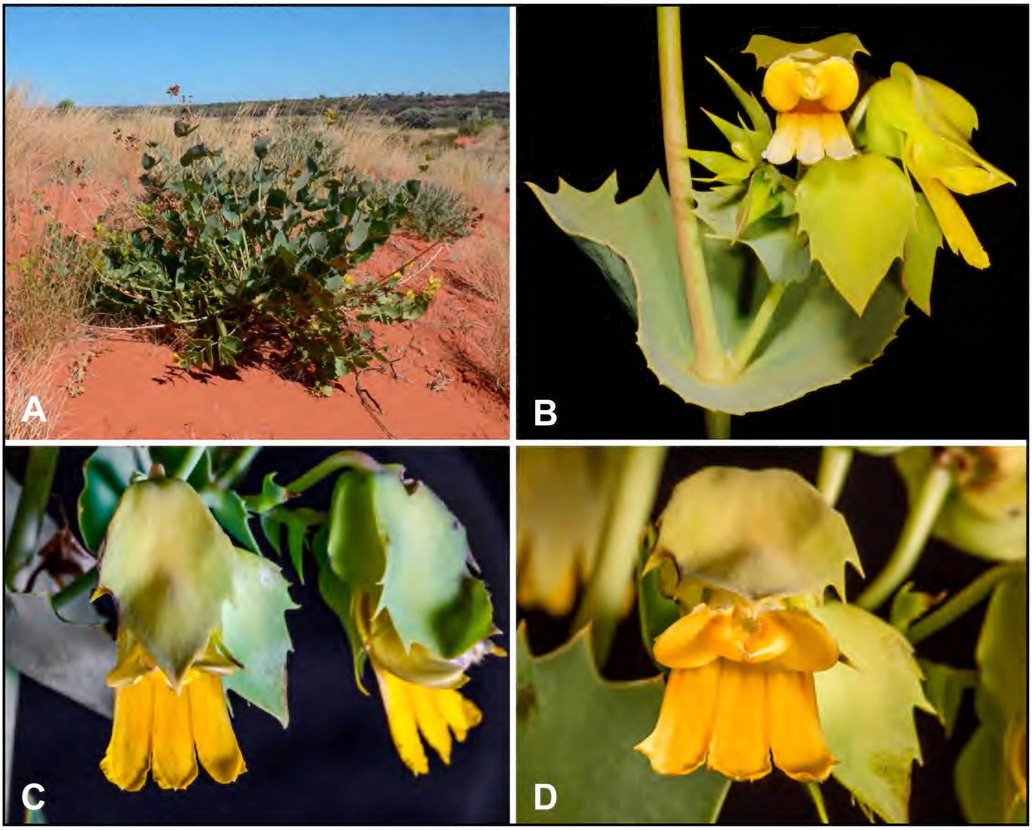

Figure 6. *Goodenia crescentiloba*. A – habit; B – disk-like bracts highlighting the crescentic to shallowly crescentic-shaped sinus between dentate lobes on the far margin; C – yellow flower viewed from above showing the broad posterior sepals fused at the base and with strongly dentate margins; D – flower, showing the long abaxial corolla lobes and auricles cupping the indusium. Vouchers: *M. Goods* DD 460 (PERTH 08749655) (A); *K.R. Thiele* 3623 (PERTH 08332134) (B); Kiwirrkurra, 2015 (unvouchered) (C, D). Images: R. Wait (A); K.R. Thiele (B), R. Whyte (C, D).

the base for 3.5–8 mm, glabrous or with a few hairs only at the margin and towards apex, acute to acuminate, with entire to shallowly dentate margins, posterior sepal 16.5–25 mm long, 8.5–13.5 mm wide; abaxial corolla wing 1.7–3.8 mm long, 0.3–1.5 mm wide, not exceeding the length of the lobe; style 8.3–10 mm long with dense hairs 1–2 mm long; and 13–18 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: 93 km W of Kiwirrkurra, 12 Sep. 2015, *R. Davis* 12678 (DNA D0285660 *n.v.*, PERTH 08850380); McLarty Hills, Great Sandy Desert, 5 Aug. 1977, *A.S. George* 14647 (CANB 292059, PERTH 02713306); Canning Stock Route, 4 km N of Well 12, 22 May 2013, *M. Goods* DD 460 (PERTH 08749655); 82 km WNW of Tanami toward Billiluna, 1 July 1971, *C.H. Gittins* 2311 (BRI AQ0000343 *n.v.,* CANB 745490, NSW 2400717); 100 km NNW Docker River, East Gibson Desert, 29 Apr. 2005, *J. Schofield* 20872 (PERTH 07311338); Canning Stock Route near Well 31, 16 Aug. 2008, *K.R. Thiele* 3623 (PERTH 08332134).

NORTHERN TERRITORY: *c.* 84 km WNW Green Swamp Well, Tanami Desert, 16 Aug. 1995, *D.E. Albrecht* 6972 (MEL 279604, NT A0091784 *n.v.*); 78 miles [125.5 km] WNW of Tanami, 13 Sep. 1972, *C.R. Dunlop* 2328 (CANB 237350, DNA A0033494 *n.v.*); on Tanami Track *c.* 472 km NW of Alice Springs (140 km SE of Rabbit Flat), 25 May 1985, *P.A. Fryxell, L.A. Craven & J. McD. Stewart*

4503 (CANB 377115, MEL 305938); Supplejack Stn, 11 km W of Eight Mile Bore, 2 Oct. 1978, *T.S. Henshall* 2375 (CBG 8101107, DNA A0064555, PAUH *n.v.*, TEX *n.v.*); 70 miles [112.6 km] N of Camp 4, 29 June 1911, *G.J. Hill* 400 (MEL 9635); 62 km SSE of Tanami Downs HS, 27 Aug. 2008, *P.K. Latz* 23709 (MEL 2479286); 13 miles [20.9 km] NW of Numagalong HS, 26 Aug. 1965, *D. Nelson & R. Swinbourne s.n.* (AD 96550480 *n.v.*, MEL 2193364, NSW 90871, NT A0011800 *n.v.*).

Phenology. Flowers observed from April to October with peak flowering in late winter. Fruits observed in May to August and in October.

Distribution and habitat. *Goodenia crescentiloba* is widespread in Western Australia and the Northern Territory, occurring in the Little Sandy Desert, Great Sandy Desert and Tanami bioregions (Figure 7). It is found growing in deep red sand with conglomerate rocks and pebbles in swale-sand plains, dune slopes, or between dunes in shallow drainage lines, in low woodland or shrublands and hummock grasslands with *Corymbia deserticola*, *C. setosa*, *Eucalyptus victrix*, *Allocasuarina decaisneana*, *Acacia* and *Triodia*.

Conservation status. This species is widespread and is not considered to be under threat.

Etymology. Formed from the English word 'crescent' and the Latin *lobus* (lobe) in reference to its distinctive, crescent-like sinus between the lobes on the margins of the bracts.

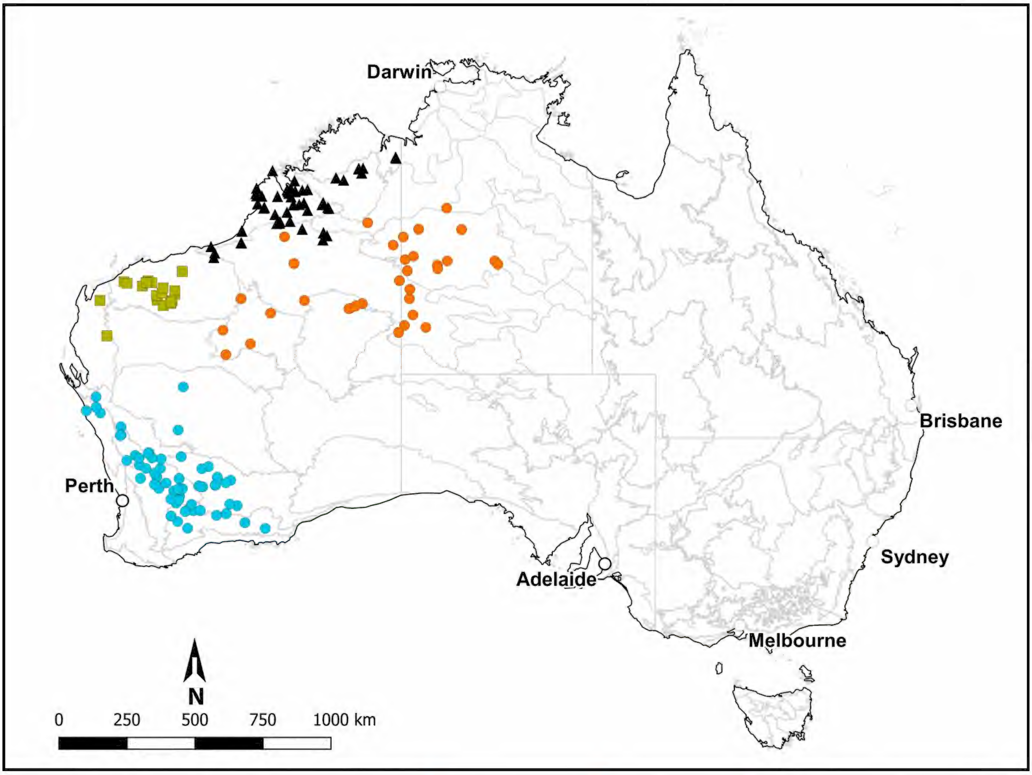

Figure 7. Distribution of *Goodenia crescentiloba* (●), *G. discophora* (●), *G. obscurata* (■) and *G. panduriformis* (▲) with IBRA subregions (Australian Government Department of Agriculture, Water and the Environment 2012) in pale grey.

Affinities. This species is similar to *G. panduriformis* in having large yellow to orange-yellow flowers. *Goodenia crescentiloba* is readily distinguished from *G. panduriformis* in having connate bracts (vs usually split to base on one side), fewer flowers per cluster ((1–)3–7 vs (7–)10–24), sepals that are basally fused for 3.5–8 mm (vs free or connate only at base) and glabrous or with a few hairs at the apex (vs hairs on both surfaces), shorter adaxial corolla lobes 10–11.5 mm long (vs 12–14.5 mm), and smaller abaxial corolla lobe wings 1.7–3.8 mm long (vs 3.8–5.5 mm).

Notes. A chromosome number of $2n = 16$, recorded by Peacock (1963) and repeated in Carolin (1967a, 1992) for *Velleia panduriformis*, may be referable to *G. crescentiloba* rather than *G. panduriformis*. Peacock records the voucher for this count as a 'seed collection' from the Northern Territory, which is within the range of *G. crescentiloba* rather than *G. panduriformis*; however, in the absence of a voucher specimen, the identity of the material used by Peacock remains unconfirmed.

Goodenia daviesii (F.Muell.) K.A.Sheph., *Phytokeys* 152: 88 (2020). *Velleia daviesii* F.Muell., *Fragm.* 10(81): 10–11 (1876). *Type*: Near Ularing, Western Australia, 1875, *Young s.n.* (*holo*: MEL 009647!).

Annual or short-lived perennial *herb*, 0.15–0.6 m high. *Leaves* in a basal rosette, obovate, narrowly ovate to spathulate, denticulate to lyrate, petiolate, lamina (including petiole) 90–135 mm long, 17–30 mm wide, with lobes 5–11.5 mm long, 2.2–6 mm wide, with scattered to dense hairs 0.3–0.5 mm long, with a densely hairy axil, apex acute, base attenuate. *Inflorescence* an elongated, branched dichasium, with terminal dichasia of 1–3(–5) flowers; peduncles 150–600 mm long including inflorescence, peduncle with scattered to dense hairs 0.2–0.6 mm long; pedicels 3–25 mm long, with moderately dense to dense hairs 0.1–0.5 mm long; bracts leaf-like, free and paired, 8–49 mm long, 11–27 mm wide, with scattered to dense hairs 0.2–0.7 mm long, and a densely hairy axil, apex acuminate to acute, margin dentate to denticulate. *Sepals* 5, basally fused for 2.3–4.5 mm, outer surface with dense hairs 0.2–0.5 mm long, inner surface with dense hairs 0.2–0.3 mm long, apex acuminate, margin strongly dentate; posterior sepal larger than the remainder, broadly ovate, free portion 11.8–13.5 mm long, 11–11.4 mm wide, remainder ovate to broadly ovate, 10.2–11.6 mm long, 6–8.5 mm wide. *Corolla* 15–20 mm long, bluish-white, rose white or creamy yellow, with scattered to dense hairs 0.1–0.3 mm long on the outer surface, inner surface with moderately dense hairs 0.3–0.4 mm long in throat and at base and faint enations; tube 2–2.8 mm long. *Adaxial corolla lobes* falcate-oblong, 9.3–11.2 mm long, 2.7–3.1 mm wide, basally fused for a further 2–3.2 mm; auricle 6–7 mm long, 2.5–3 mm wide, with dense hairs 0.6–1.2 mm long on the inner margin; wing above auricle 3.7–4 mm long, 0.8–1.8 mm wide, wing opposite auricle 1.7–2.2 mm long, 0.6–0.8 mm wide. *Abaxial corolla lobes* ovate, 4.8–6 mm long, 3.3–4 mm wide, basally fused for a further 10–10.2 mm, wings 2.5–6.5 mm long, 0.5–1.5 mm wide, exceeding the length of the lobe by 0.3–2.1 mm. *Stamens* 5, filaments 3.2–4 mm long, 0.5–0.7 mm wide; anthers linear, 2.4–3.1 mm long, 0.9–1.4 mm wide. *Style* 5–6.3 mm long, 1.7–2 mm wide, with moderately dense to dense hairs 0.7–1.3 mm long; indusium broadly obovoid, 2.5–3 mm long, 4.3–4.4 mm wide, abaxial surface with moderately dense hairs 0.7–1.2 mm long, adaxial surface with moderately dense to dense hairs 0.3–1.1 mm long, upper lip with dense bristles 0.8–1 mm long, lower lip glabrous or with bristles 0.5–0.6 mm long towards the edges. *Ovary* elliptic to obovate, 2.3–6.2 mm long, 2.3–6 mm wide, glabrous, septum obsolete or with residual tissue, with 30–34 ovules. *Fruit* a capsule, ovoid, glabrous, 7–10 mm long, 7.5–10 mm wide. *Seeds* ovate, flat, light brown, 3–3.8 mm long, 2.1–2.5 mm wide, smooth or with faint pits over the surface; wing golden brown, not overlapping seed margin, 1–1.4 mm wide.

Diagnostic features. Uniquely characterised within the genus by the following features: bracts leaf-like, free and paired, with scattered to dense hairs 0.2–0.7 mm long, acuminate to acute with dentate to denticulate margins; terminal dichasia of 1–3(–5) flowers with a bluish white, rose white or creamy yellow corolla 15–20 mm long; pedicels with moderately dense to dense hairs 0.1–0.5 mm long; sepals fused at the base for 2.3–4.5 mm, with dense hairs 0.2–0.5 mm long on the outer surface, acuminate with strongly dentate margins, posterior sepal 11.8–13.5 mm long, 11–11.4 mm wide; abaxial corolla wings 2.5–6.5 mm long, 0.5–1.5 mm wide, exceeding the length of the lobe by 0.3–2.1 mm; style 5–6.3 mm long, with moderately dense to dense hairs 0.7–1.3 mm long; and 30–34 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: Roe Botanical District, 17 km N of Mt Buraminya, 23 Nov. 1991, *W.R. Archer* 2311912 (MEL 2019307); 1 mile E of Woolgangie, 2 Nov. 1947, *J.H.Calaby s.n.* (CANB 15011); Quadrat LMS8, Lake Mason Stn, N of Sandstone, 14 Sep. 2005, *D.J. Edinger* 5436 (PERTH 07284039); Site ll, Lake Mason, Lake Mason Stn, 56 km NNE of Sandstone, 14 April 2004, *D.J. Edinger & G. Marsh* DJE 4008 (PERTH 06794726); 30 miles [48 km] W of Balladonia towards Fraser Range, 26 Oct. 1931, *C.A. Gardner* 2912 (CANB 00539269‘ PERTH 02569175); near Derby, July 1967, *C. H. Gittins* 1445 (NSW 807648); *c.* 5 km E of Derby, Broome road, 22 May 2008, *S.W.L. Jacobs* 9868 (CANB 726309, NSW 874780); 4 km NE of Comet Vale, 18 Oct. 1987, *G.J. Keighery* 9437 (PERTH 02764164); Coolgardie Goldfields, Oct. 1901, *E. Pritzel* 850 (NSW 75659); 18 miles [28.9 km] W of Old Gidgee HS, N of Sandstone, 16 Oct. 1972, *R.D. Royce* 10445 (PERTH 01875329); 11.9 km N Lake Barlee HS, Lake Barlee, 19 Oct. 2003, *L. Sweedman* 6192 (PERTH 06868215); 25.7 miles SW of Coolgardie on the Great Eastern Hwy, 9 Mar. 1970, *M.D. Tindale & E.M. Bennett* 43 (NSW 105109); 9 miles [14.4 km] E of Kurnalpi, 11 Oct. 1974, *E. Wittwer* 1357 (PERTH 02764237).

Phenology. Flowers recorded from September to November. Fruits recorded in May and October.

Distribution and habitat. Restricted to Western Australia, extending from south-east of Meekatharra to west of Balladonia in the Coolgardie and Murchison bioregions, with a single southernmost population in the Mallee bioregion to the south of Dundas Nature Reserve (Figure 3). It is found growing on plains or salt flats in red sand or sandy loam associated with *Eucalyptus georgei*, or in red clay loam over limestone in open mallee with *Triodia*.

Conservation status. This species is relatively widespread and is not considered to be under threat.

Affinities. *Goodenia daviesii* is morphologically most similar to the hairy southern Western Australian specimens of *G. connata* (see notes under that species) but can be recognised by the presence of free bracts (vs usually connate), peduncles with dense hairs 0.1–0.5 mm long (vs glabrous or with scattered hairs 0.1–0.3 mm long), pedicels with dense hairs 0.1–0.5 mm long (vs glabrous or scattered to moderately dense hairs 0.1–0.5 mm long), and a bluish white to rose white or creamy yellow corolla 15–20 mm long (vs a cream, white, whitish green to pale violet, pinkish mauve or yellowish pink corolla 16–25 mm long).

Goodenia discophora (F.Muell.) K.A.Sheph., *PhytoKeys* 152: 89 (2020). *Velleia discophora* F.Muell., *Fragm*. 10(81): 10 (1876). *Type*: Near Ularing, Western Australia, 10–15 October 1875, *Young s.n.* (*holo*: MEL 009649!).

Annual or short-lived perennial *herb*, 0.3–0.7 m high. *Leaves* arranged in a basal rosette, petiolate, narrowly ovate, spathulate to lyrate, denticulate to dentate, lamina (including petiole) 55–300 mm long, 16–50 mm wide, with lobes 5–30 mm long, 5–14 mm wide, glabrous, with a densely hairy axil, apex acute to rounded, base attenuate. *Inflorescence* an elongated, branched dichasium, with terminal dichasia of 1 or 2 flowers; peduncles 300–700 mm long including inflorescence, glabrous; pedicels

2–30 mm long, glabrous; bracts connate into a disk, not slit to the base, 11.5–80 mm diam., glabrous, with a densely hairy axil, apex rounded or with a small apiculus, margin entire. *Sepals* 5, basally fused for 1.5–2.2 mm, both surfaces glabrous, apex acute, margin entire; posterior sepal slightly larger than the remainder, narrowly ovate, free portion 5.9–6.1 mm long, 1.4–5.5 mm wide, remainder narrowly ovate, 4.1–6 mm long, 2–3 mm wide. *Corolla* 16–19 mm long, yellow with a deep orange throat, glabrous on the outer surface, inner surface with dense hairs in the throat 0.2–0.4 mm long, sometimes with faint enations; tube 3–3.5 mm long. *Adaxial corolla lobes* falcate-oblong, 6.9–7.5 mm long, 2–2.5 mm wide, basally fused for a further 3.2–4 mm; auricle 2.8–3 mm long, 1.4–1.5 mm wide, with dense hairs 0.3–0.6 mm long on the inner margin; wing above auricle 3.3–5 mm long, 1.1–1.8 mm wide, wing opposite auricle 3.2–6 mm long, 0.5–2 mm wide. *Abaxial corolla lobes* oblong, 4.3–8.3 mm long, 1.8–2.7 mm wide, basally fused for a further 5.5–6 mm, wing 2.4–8.2 mm long, 0.8–2.2 mm wide, extending 0.1–1.2 mm beyond the lobe apex. *Stamens* 5, filaments 2.1–3 mm long, 0.3–0.5 mm wide; anthers linear, 1.6–1.8 mm long, 0.6–1.5 mm wide. *Style* 3–3.5 mm long, 0.7–1 mm wide, with scattered to moderately dense hairs 0.2–0.3 mm long; indusium obovoid, 2.1–2.2 mm long, 2.4–2.5 mm wide, abaxial surface with scattered to moderately dense hairs 0.2–0.5 mm long, adaxial surface with moderately dense hairs 0.2–0.4 mm long, upper lip with dense bristles to 0.4–0.6 mm long, lower lip glabrous with bristles to 0.1 mm long. *Ovary* elliptic, 2.7–1.2 mm long, 2–2.5 mm wide, glabrous, septum almost obsolete, with 12–15 ovules. *Fruit* a capsule, elliptic to ovoid, glabrous, 7–12 mm long, 9–14 mm wide. *Seeds* ovate, flat, brown, 2.5–3 mm long, 1.8–2 mm wide, with small projections over the surface; wing golden brown, not overlapping seed margin, 1.3–1.5 mm wide. (Figure 8)

Diagnostic features. Distinguished within *Goodenia* by the following features: bracts connate into a disk, not slit to the base, 11.5–80 mm diam., glabrous, apex rounded or with a small apiculus, margins entire; terminal dichasia of 1 or 2 flowers; a yellow corolla 16–19 mm long with deep orange throat; pedicels glabrous; sepals fused at the base for 1.5–2.2 mm, glabrous, acute with entire margins, posterior sepal 5.9–6.1 mm long, 1.4–5.5 mm wide; abaxial corolla wings 2.4–8.2 mm long, 0.8–2.2 mm wide, extending 0.1–1.2 mm beyond the lobe apex; style 3–3.5 mm long, with scattered to moderately dense hairs 0.2–0.3 mm long; and 12–15 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: Roe Botanic District. 10.5 km NNE of Mt Heywood, 14 Dec. 1991, *W.R. Archer* 1412913 (MEL 2019308, PERTH 03590054); Roe Botanic District. 16.5 km NNE of Mt Heywood, 28 Dec. 1991, *W.R. Archer* 28129119 (MEL 2019310); Roe Botanic District. 23 km NE of Mt Heywood, 28 Dec. 1991, *W.R. Archer* 2812919 (MEL 2019309); Yellowdine, 32 km E of Southern Cross along Great Eastern Hwy towards Coolgardie, 30 Jan. 1979, *B.Barnsley* 1007 (CBG 7902345); 13 miles [20.9 km] E of Meekatharra, 8 Dec. 1955, *N.T. Burbidge* 4718 (CANB 34049, PERTH 2692457); Geraldton to Mt Magnet Rd, 14 miles [22.5 km] E of Mullewa, 10 Sep. 1966, *R. Filson* 8702 (MEL 0033377); Gnarlbine, 12 Nov. 1891, *R. Helms s.n.* (MEL 0009650); *c.* 60 km direct NE of Wubin, *c.* 19 km direct SW of Mt Gibson, 1.5 km E of Great Northern Hwy along road to Mt Gibson gold mine, 24 Oct. 1992, *A.M. Lyne, L. Craven & F. Zich* AML 856 (AUA *n.v.,* CBG 9215700, E *n.v.,* MU *n.v.,* PERTH 09159614); Corridors (Koolyanobbing, Windarling, Mt Jackson), 16 Oct. 2000, *E. Mattiske* J 39–156 (MEL 2286925, NSW 536939, PERTH 06351255); *c.*15 km E of Mullewa, 4 Oct. 1966, *E.A. Shaw* 635 (AD 96832258 *n.v.*, CANB 537224); 20.9 km SE of Victoria Rocks Rd on Hyden–Norseman Rd, E of Norseman, 6 Oct. 2011, *K.A. Shepherd, C.F. Wilkins & J.A. Wege* KS 1467 (PERTH 09198334); 3.6 km E of Burgess Rd on Dinnie Rd, 24 Sep. 2013, *K.A. Shepherd & S.R. Willis* KS 1513 (PERTH 08616302); Borrikin Rock, 19 Sep. 1982, *B.H. Smith* 122, (NSW 2400724, MEL 624758); 7.88 miles [12.6 km] E of No. 1 Rabbit fence on track to Clampton, 22 Oct. 1995, *B.H. Smith* 1811 (MEL 2369206, PAL *n.v.*, PERTH 09229302, S *n.v.*); Wilroy, 14 Sep. 1959, *R.F. Thorne* 24495 (RSA *n.v.*, MEL 2476583); Along track to Orchid corner, Eurardy Bush Heritage Reserve, Kalbarri, 19 Aug. 2008, *J.E. Wajon* 1714 (PERTH 08338906).

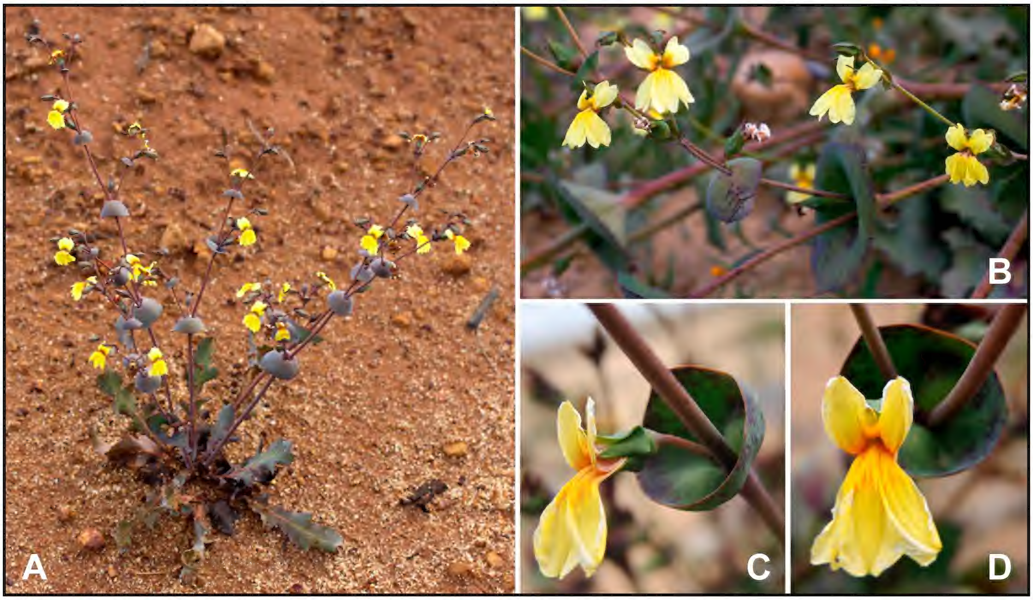

Figure 8. *Goodenia discophora*. A – habit; B – flowering stem; C – solitary yellow flower showing the connate bracts and narrow sepals divided to near the base; D – flower showing the obvious wings on the abaxial corolla lobes. Vouchers: *K.A. Shepherd, C.F. Wilkins & J.A. Wege* KS 1467 (PERTH 09198334) (A); *J.E. Wajon* 1714 (PERTH 08338906) (B); *K.A. Shepherd & S.R. Willis* KS 1513 (PERTH 08616302) (C, D). Images by: K.A. Shepherd (A, C, D); J.E. Wajon (B).

Phenology. Flowers recorded from September to December. Fruits recorded from May to January.

Distribution and habitat. Restricted to Western Australia, occurring in the Avon Wheatbelt, Coolgardie, Geraldton Sandplains, Mallee, Murchison and Yalgoo bioregions (Figure 7). Grows in grey or yellow sand or reddish brown loam over laterite or granite, in open mallee or low woodland over heath with *Acacia*, *Allocasuarina acutivalvis*, *Gyrostemon ramulosus*, *Thryptomene* and *Seringia*.

Conservation status. Widespread and currently not considered to be at risk.

Affinities. This species is morphologically most similar to *G. obscurata* in having generally smaller flowers with less than 20 ovules in each ovary. *Goodenia discophora* is distinguished from *G. obscurata* in having a yellow corolla with a deep orange throat (vs a white corolla with a yellow throat), and narrower sepals (posterior sepal 1.4–5.5 mm wide vs 6.2–7 mm wide) that are more shortly fused at the base (1.5–2.2 mm vs 2.3–3.8 mm).

Goodenia obscurata K.A.Sheph. & Lepschi, *sp. nov.*

Type: Hamersley Range, Chichester-Millstream National Park, 20 km E of Millstream Junction, Western Australia, 4 October 1989, *B. Nordenstam & A. Anderberg* 313 (*holo*: PERTH 01947729!; *iso*: CANB, MEL 2191030!, NSW 2400728!).

Annual or short-lived perennial *herb*, 0.35–0.6 m high. *Leaves* in a basal rosette, obovate, denticulate, petiolate, lamina (including petiole) 54–73 mm long, 24–25 mm wide, glabrous, with a densely hairy axil, apex rounded, base attenuate. *Inflorescence* an elongated, branched dichasium, with terminal dichasia of 1 or 2 flowers, peduncles 350–600 mm long including inflorescence, glabrous; pedicels

4–25 mm long, glabrous; bracts connate into a disk, not slit to the base, 9–63 mm diam., glabrous, with a densely hairy axil, apex rounded with an apiculus to shallowly acute, margin entire to shallowly denticulate. *Sepals* 5, basally fused for 2.3–3.8 mm, both surfaces glabrous, apex acute to acuminate, margin entire; posterior sepal larger than the remainder, ovate, free portion 5.5–7.5 mm long, 6.2–7 mm wide, remainder ovate, 4.4–7.2 mm long, 3–4.8 mm wide. *Corolla* 14–19 mm long, white or very pale pink with a yellow throat, glabrous on the outer surface, inner surface with scattered to moderately dense hairs 0.2–0.5 mm long in the throat and faint enations; tube 1.8–2.6 mm long. *Adaxial corolla lobes* falcate-oblong, 6.5–10.3 mm long, 1.3–3 mm wide, basally fused for a further 1.5–3 mm; auricle 4–7 mm long, 1.4–2.6 mm wide, with dense hairs 0.4–1.2 mm long on the inner margin; wing above auricle 2–3 mm long, 0.7–3 mm wide, with scattered hairs, wing opposite auricle 1.1–5 mm long, 0.4–1.2 mm wide. *Abaxial corolla lobes* oblong, 3.2–5.4 mm long, 3.2–5 mm wide, basally fused for a further 7.1–10.6 mm, wings 2.4–5.7 mm long, 0.6–1.6 mm wide, exceeding the length of the lobe by 0.1–0.4(–0.6) mm. *Stamens* 5, filaments 3–3.6 mm long, 0.5–0.7 mm wide; anthers linear, 1.8–2.7 mm long, 0.5–1.1 mm wide. *Style* 4.7–6 mm long, 0.8–1.3 mm wide, very few to scattered hairs 0.3–1.2 mm long; indusium broadly obovoid, 2–2.7 mm long, 3.2–5 mm wide, abaxial surface with scattered hairs 0.3–0.6 mm long, adaxial surface with scattered hairs 0.3–1 mm long, upper lip with dense bristles 0.6–1.4 mm long, lower lip glabrous or with bristles 0.1–0.3 mm towards the edges. *Ovary* elliptic to obovoid, 1.8–3 mm long, 2–2.7 mm wide, glabrous, septum obsolete, with 11–16 ovules. *Fruit* a capsule, globular to ovoid, glabrous, 9–11 mm long, 8–12 mm wide. *Seeds* ovate, flat, brown, 3.6–4.4 mm long, 2.5–3.3 mm wide, punctulate; wing pale brown, not overlapping seed margin, 0.7–1.8 mm wide. (Figure 9)

Diagnostic features. *Goodenia obscurata* is distinguished by the following characters: bracts connate into a disk, not slit to the base, glabrous, apex rounded with an apiculus or shallowly acute, margins entire to shallowly denticulate; terminal dichasia of 1 or 2 flowers with a white or very pale pink corolla 14–19 mm long; pedicels glabrous; sepals fused for 2.3–3.8 mm, glabrous, acute to acuminate, with entire margins, posterior sepal 5.5–7.5 mm long, 6.2–7 mm wide; abaxial corolla wings 2.4–5.7 mm long, 0.6–1.6 mm wide, exceeding the length of the lobe by 0.1–0.4(–0.6) mm; style 4.7–6 mm long, with very few to scattered hairs 0.3–1.2 mm long; and 11–16 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: 2 miles [3.2 km] from Mount Bruce, Fortescue [District], 26 Sep. 1965, *J.V. Blockley* 88 (PERTH 06035264); *c.* 74 km SE of Pannawonica, 5 May 2023, *L.I. Buchan Rivas & J. Alford* K087-02 (PERTH 09575227); Abydos-Woodstock Rd, S of Port Hedland, 26 Apr. 1958, *N.T. Burbidge* 5888 (CANB 53758); Adjacent to homestead airstrip; Yanrey Stn, 9 May 2004, *G. Byrne* 965 (PERTH 07407157); Adjacent to Millstream Chichester NP, W side of road, 18.9 km W of junction with main Millstream Chichester National Park entry road on Millstream–Pannawonica Rd, 10.6 km NNW of Mt Flora, 66.6 km ESE of Pannawonica, 1 Sep. 2015, *S. Caddy-Retalic* WAA 008427 (PERTH 09202927); Near the Lyndon River, 1885, *H.S. Carey s.n.* (MEL 9631); Hood Bore, Coolawanyah Stn, 85 km N of Tom Price, 25 June 2011, *A. Douglas* WB 30824 (PERTH 08673233); Roadside 139.2 km N of Kumarina, 23 Aug. 1985, *Hj. Eichler* 23594 (CANB 364006); Hamersley Range, on summit, 24 Aug. 1932, *C.A. Gardner* 3150 (CANB 00539272, PERTH 02569191); Mt Elvire, 41.8 km NNE of Mt Rica, 22.7 km WSW of Mt Flora, 17.2 km ESE of River Well on the Robe River, Yalleen Stn, Hamersley Range, 14 Oct. 1998, *S. van Leeuwen* 4310 (CANB 538620, MEL 2425488, PERTH 06110819); Pannawonica–Millstream Rd, 11 km W of entrance to Millstream, 18 July 2004, *J.E. Wajon* 1060 (DNA D0276552, PERTH 07349254); NW roadside *c.* 2.5 miles (4 km) W of Gordon Oxer Lookout (onto Red & Hancock Gorges), Hamersley Ra. National Park, 16 Aug. 1974, *J.H. Willis s.n.* (MEL 2193368).

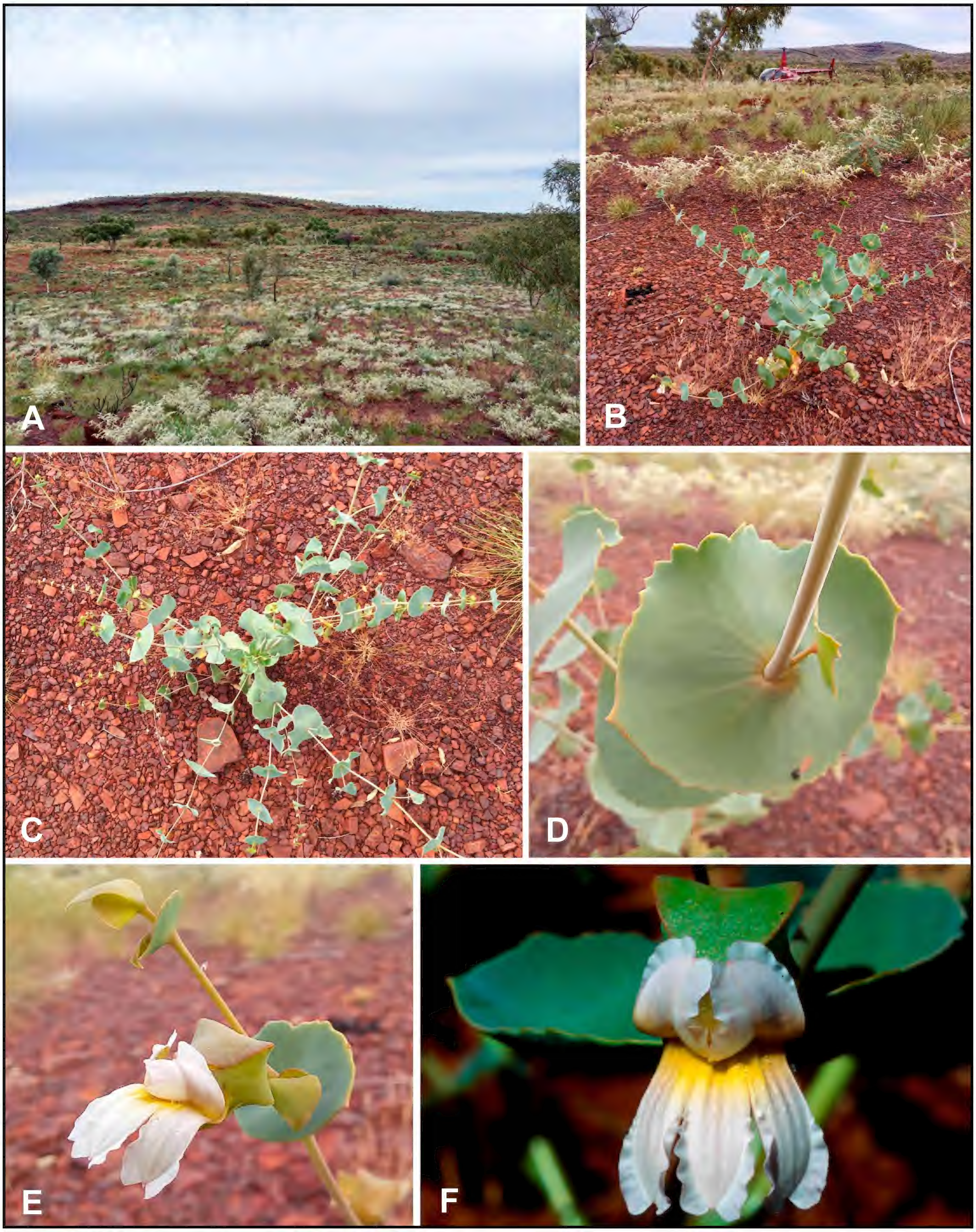

Figure 9. *Goodenia obscurata*. A – habitat; B – habit; C – whole plant comprised of flowering stems; D – connate, disk-like bracts; E – side view of flower showing the broad obovate sepals; F – white and yellow flower highlighting the broad posterior sepal with entire margins and the wings on the adaxial and abaxial corolla lobes that do not extend far beyond the apex of each lobe. Vouchers: *L.I. Buchan Rivas & J. Alford* K087-02 (PERTH 09575227) (A– E); *J.E. Wajon* 1060 (PERTH 07349254) (F). Images by: L.I. Buchan Rivas (A– E); J.E. Wajon.

Phenology. Flowers recorded April, May and August to October. Fruits recorded April to October.

Distribution and habitat. Restricted to Western Australia and extending across the western Pilbara, with a single population recorded from the Carnarvon bioregion, inland from the Exmouth Gulf (Figure 7). Occurs on floodplains or low rocky ridges, growing in red-brown sandy clay or lateritic loam over banded ironstone. Associated with low open woodland of *Acacia* over *Triodia*, or open shrubland with a sparse overstorey of *Corymbia hamersleyana* and *Hakea chordophylla* over *Triodia*.

Conservation status. To be listed as Priority Three under Conservation Codes for Western Australian flora (Tanya Llorens pers. comm.). An under-surveyed species that is mostly known from mining tenements.

Etymology. From the Latin *obscurata* (obscured), in reference to this taxon having been overlooked within the genus. Most material of this species has previously been referred to an expanded and ill-defined *G. connata*.

Affinities. See comments under *G. discophora* and *G. connata*.

Goodenia panduriformis (A.Cunn. ex Benth.) K.A.Sheph., *PhytoKeys* 152: 91 (2020). *Velleia panduriformis* A.Cunn. ex Benth., *Fl. Austral.* 4: 46 (1868). *Lectotype*, first-step designated by Carolin, *Proc. Linn. Soc. New South Wales* 92(1): 36 (1967): 'Goodenough Bay and Point Cunningham, N.W. Coast, A. Cunningham (K)'; second-step designated by K.A. Shepherd *et al.*, *Phytokeys* 152: 91 (2020): 'Australia: Western Australia. Point Cunningham & Carlisle Head, the North Point of Goodenough Bay', *s. dat.*, [*A. Cunningham s.n.*] (K 000215368 image!; *isolecto*: BM 00104382 image!, K 000215367 image!, MEL 0009640!).

Robust annual or short-lived perennial *herb*, 1–1.5 m high. *Leaves* in a basal rosette, obovate, denticulate to shallowly or very shallowly dentate, petiolate, lamina (including petiole) 46–100 mm long, 17–55 mm wide, glabrous, with a densely hairy to floccose axil, apex rounded, base attenuate. *Inflorescence* an elongated, branched dichasium, with lateral branches at each node growing more strongly than the others giving a superficial appearance of a cluster, with terminal dichasia of (7–)10–24 flowers; peduncles 1000–1500 mm long including inflorescence, glabrous or with moderately dense hairs 0.1–0.3 mm long basally; pedicels 5.5–15 mm long, glabrous, or with scattered to moderately dense hairs 0.1–0.3 mm long basally; bracts connate into a disk usually slit nearly to the base on one side, 3.6–140 mm diam., glabrous or with scattered hairs 0.1–0.4 mm long, with a densely hairy axil, apex rounded to acute, margin very shallowly dentate to shallowly dentate. *Sepals* 5, free or barely fused at base, outer surface with scattered to dense hairs 0.1–0.3 mm long, sometimes restricted to margins and apex only, inner surface and margin usually with scattered to moderately dense hairs 0.1–0.2 mm long, apex acute to acuminate, margin entire to shallowly dentate; posterior sepal larger than the remainder, broadly ovate to elliptic, 20–22 mm long, 11–15.8 mm wide, remainder narrowly ovate to lanceolate, 14.6–17.5 mm long, 5.6–7 mm wide. *Corolla* orange yellow, 25–29 mm long, glabrous on the outer surface or with scattered hairs 0.2–0.3 mm long, inner surface with dense hairs 0.3–0.6 mm long in throat and faint enations; tube 1.5–3 mm long. *Adaxial corolla lobes* falcate-oblong, 12–14.5 mm long, 2.5–4 mm wide, basally fused for a further 4.2–6 mm; auricle 5–6.5 mm long, 2–3.5 mm wide, with dense hairs 1.3–1.5 mm long on the inner margin; wing above auricle 2.4–3.5 mm long, 0.6–2 mm wide, with dense hairs, wing opposite auricle 3.3 mm long, 1–1.9 mm wide. *Abaxial corolla lobes* oblong, 4.8–5.2 mm long, 3–3.5 mm wide, basally fused for a further 13–15 mm, wing 3.8–5.5 mm long, 1.2–1.7 mm wide, not exceeding the length of the lobe. *Stamens* 5, filaments 4.6–5.2 mm long, 0.7–0.8 mm wide; anthers linear, 3.3–3.8 mm long, 0.7–0.9 mm wide. *Style* 9.2–10 mm long, 1.1–1.5 mm wide, with scattered hairs 0.6–1.5 mm long; indusium obovoid, sometimes slightly curved inwards, 3.3–4 mm long, 3.2–4 mm wide, abaxial surface glabrous or with moderately dense hairs 0.6–1.5 mm long, adaxial surface with scattered to moderately dense hairs to 2 mm long, upper lip with dense bristles 1–1.1 mm long, lower lip with short bristles 0.1 mm long. *Ovary* elliptic, 4–5 mm long, 3–3.2 mm wide, glabrous, septum incomplete and less than one third length, with 14 ovules. *Fruit* a capsule ovoid, glabrous, *c.* 10.6 mm long, *c.* 9 mm wide. *Seeds* ovate, flat, pale brown, 5.2–7.2 mm long, 4.7–6 mm wide, smooth with faint pits or projections towards the margin; wing fawn to pale yellow, not overlapping seed margin, 1.8–3.2 mm wide, punctulate. (Figure 10)

Diagnostic features. Distinguished from allied species by the following combination of characters: robust habit 1–1.5 m high; bracts connate into a disk usually slit to near the base, apex rounded to acute, margins very shallowly to shallowly dentate; terminal clusters of (7–)10–24 flowers with an orange yellow corolla 25–29 mm long; pedicels glabrous or with scattered to moderately dense hairs 0.1–0.3 mm long basally; sepals free or almost free, outer surface with scattered to dense hairs 0.1–0.3 mm long (hairs sometimes restricted to margins and apex), apex acute to acuminate, margins entire to shallowly dentate; posterior sepal 20–22 mm long, 11–15.8 mm wide; abaxial corolla wings 3.8–5.5 mm long, 1.2–1.7 mm wide, not exceeding the length of the lobe; style 9.2–10 mm long with scattered hairs 0.6–1.5 mm long; and 14 ovules per flower.

Selected specimens examined. WESTERN AUSTRALIA: Broome lighthouse area, 7 Aug. 1965, *A.C. Beauglehole* ACB 11273 (MEL 0623269, PERTH 02713489); Anna Plains Track to Great Northern Hwy, 0.8 km from homestead, 15 Sep. 2004, *G. Byrne* 1214 (PERTH 07160992); 'Robert', northern Great Sandy Desert, 19 Aug. 2001, *C.P. Campbell* 3287 (PERTH 05935164); 2 km N of Shay Gap township, 13 Sep. 1982, *L.A. Craven* 7563 (CANB 379538, MEL 0304474, PERTH 02713241); Barnett River crossing on the Derby–Kununurra Rd, 30 June 1984, *L. Craven* 8451 (AD 99401234 *n.v.*, CANB 399445, DNA D0120977, MEL 0235156, PERTH 3590046); 35 km S along Boreline Rd from Great Northern Hwy, *c.* 40 km E of Pardoo Roadhouse, 5 Oct. 2008, *T. Erickson* TEE 587 (PERTH 08141495); Yeeda 28 miles [45 km] S.E. Derby, Apr. 1927, *A.J. Ewart s.n.* (MEL 2193258); *c.* 5 km E of Derby, Broome road, 22 May 2008, *S.W.L. Jacobs* 9868 (CANB 00726309, NSW 874780, PERTH 9590722); R2. Edgar Ra. site, Edgar Ra., SE of Broome, 7 Aug. 1976, *K.F. Kenneally* 5528 (CANB 288808, PERTH 01626345); Leopold Downs Road, 1 km N of junction with Great Northern Hwy (Hwy 1), 8 June 2022, *C.T. Martine, T.M. Williams, C. Marino & A. Wrobleski* CTM 5061 (BUPL *n.v.*, PERTH 09504362); Oscar Range, 15 km from Great Northern Hwy along road to Tunnel Creek National Park, Dampier District, 12 May 1999, *R.W. Purdie* 4894 (CANB 604320, PERTH 05945879); Karunjie Stn, Kimberleys, Nov. 1954, *D.W. Rust* 2K (CANB 109410); 16 miles [25.7 km] NE of Karunjie Stn, Kimberleys, 14 Sep. 1954, *N.H. Speck* 5011 (CANB 109409); *c.* 40 km E of Derby along Gibb River road, 14 Aug. 1977, *I.R. Telford* 6905 & *G. Butler* (CBG 7708437, NSW 2400713); Broome, Gantheaume Point, 15 May 1992, *I.R. Telford* 11733 (CBG 9206387, NSW 2400715); Roebuck Bay, Nov. 1889, *J.W.O. Tepper* 59 (MEL 0009642); Kavite Road, Riddel Beach Area, Broome Port District, 21 Sep. 2011, *J.O. Westaway* 3666 (CANB 00818636, DNA D0227777); Great Northern Hwy, 5 miles [8 km] W of Fitzroy Crossing, Kimberleys, 19 July 1974, *J.H. Willis s.n.* (MEL 2118689, MEL 2118690).

Phenology. Flowers recorded from May to November with peak flowering apparently occurring June to September. Fruits recorded July to September.

Distribution and habitat. *Goodenia panduriformis* is found across the western and central Kimberley of Western Australia in the Dampierland, Great Sandy Desert and Central Kimberley bioregions

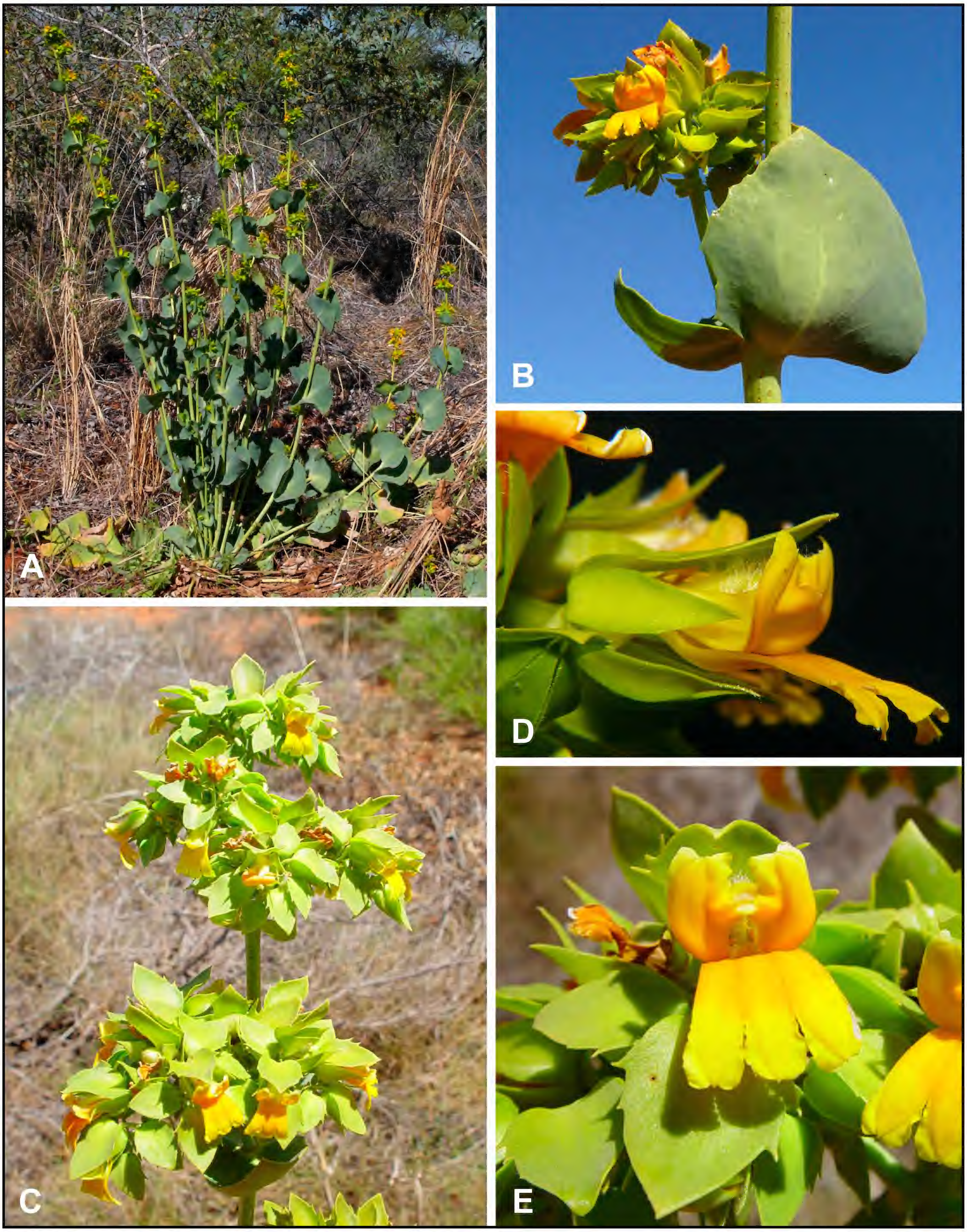

Figure 10. *Goodenia panduriformis*. A – habit; B – disk-like bracts split on one side; C – large clusters of terminal flowers; D – flower, side view showing the narrowly ovate sepals split to the base, and long abaxial corolla lobes; E – orange yellow corolla showing adaxial lobes and auricles cupping the indusium. Vouchers: *c.* 50 km W Mt Hardman, WA, 2010 (unvouchered) (A, B, D); *G. Byrne* 1214 (PERTH 07160992) (C, E). Images by: S. & A. Pearson (A, B, D); G. Byrne (C, E).

(Figure 7). Grows on pindan sandplains, between dunes, or on coastal cliffs in deep red sand, red loam or brown sandy loam, sometimes over sandstone, and is associated with low open woodlands, shrublands or *Triodia* communities.

Conservation status. This species is relatively widespread and is not considered to be under threat.

Affinities. See comments under *G. crescentiloba*.

Notes. A chromosome number of $2n = 16$, recorded by Peacock (1963) and repeated in Carolin (1967, 1992) for *Velleia panduriformis* may be referable to *G. crescentiloba* rather than *G. panduriformis* (see notes under *G. crescentiloba* for further discussion).

Acknowledgements

We gratefully acknowledge AD, BRI, DNA, NT and their staff for organising loan material to be sent to PERTH for study; Helen Barnes, Eugenia Pacitti, Peter Jobson, Hannah McPherson, Lisa Woods, and staff at MEL and NSW respectively for hosting our visits to examine their collections; the curation staff at PERTH including Cheryl Parker, Julia Percy-Bower and Renee Gugiatti for their support and for completing thorough editorial checks on the selected specimens; the Goodeniaceae Study Group of Australian Plants Society for their support; and the following for their kind consent in allowing the use of their images – Dave Albrecht, Graham Byrne, Luis Buchan Rivas, Maree and Graham Goods, Charlie Nicholson, Steve and Alison Pearson, Kevin Thiele, Eddy Wajon, Russell Wait and Robert Whyte. David Albrecht is thanked for providing a thoughtful review and Juliet Wege for her insightful editorial comments.

References

Albrecht, D.E. (2002). New species and notes on central Australian *Goodenia* (Goodeniaceae). *Nuytsia* 15(1): 1–9.

Australian Government Department of Agriculture, Water and the Environment (2012). Australia's bioregions (IBRA). https://www.dcceew.gov.au/environment/land/nrs/science/ibra [accessed 3 July 2023].

Bottomley, W. & White, D.E. (1951). The chemistry of Western Australian plants. V. vellein from *Velleia discophora*. *Australian Journal of Chemistry* 4(1): 112–115.

Briggs, B.G. & Johnson, L.A.S. (1979). Evolution in the Myrtaceae – evidence from inflorescence structure. *Proceedings of the Linnean Society of New South Wales* 102: 157–256.

Carolin, R.C. (1967a). The genus *Velleia* Sm. *Proceedings of the Linnean Society of New South Wales* 92: 27–57.

Carolin, R.C. (1967b). The concept of the inflorescence in the order Campanulales. *Proceedings of the Linnean Society of New South Wales* 92: 7–26.

Carolin, R.C. (1992). *Velleia*. *In*: George, A.S. (ed.), *Flora of Australia*. Vol. 35, pp. 282–297. (Australian Biological Resources Study: Canberra.)

Gardner, C.A. & Bennetts, H.W. (1955). Poison plants of Western Australia – Cabbage poison (*Velleia discophora* F. Muell.). *Journal of the Department of Agriculture, Western Australia*, Series 3, 4(2): 192–194.

Peacock, W.J. (1963). Chromosome numbers and cytoevolution in the Goodeniaceae. *Proceedings of the Linnean Society of New South Wales* 88: 8–27.

Shepherd, K.A., Lepschi, B.J., Johnson, E.A., Gardner, A.G., Sessa, E.B. & Jabaily, R.S. (2020). The concluding chapter: recircumscription of *Goodenia* (Goodeniaceae) to include four allied genera with an updated infrageneric classification. *PhytoKeys* 152: 27–104. doi: 10.3897/phytokeys.152.49604

The State of Victoria Department of Environment, Land, Water and Planning (2023). *Flora and Fauna Guarantee Act 1988 – Threatened List May 2023*. https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list [accessed 24 May 2023].

Turland, N.J., Wiersema, J.H., Barrie, F.R., Greuter, W., Hawksworth, D.L., Herendeen, P.S., Knapp, S., Kusber, W.-H., Li, D.-Z., Marhold, K., May, T. W., McNeill, J., Monro, A.M., Prado, J., Price, M.J. & Smith, G.F. (eds) (2018). *International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017*. Regnum Vegetabile 159. (Glashütten: Koeltz Botanical Books). doi: https://doi.org/10.12705/Code.2018

Watson, E.M. (1946). The chemistry and the chemical exploitation of Western Australian plants. Presidential Address, 1944. *Journal of the Royal Society of Western Australia* 30: 83–104.

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dbca.wa.gov.au/ [accessed 29 August 2023].

Nuytsia The journal of the Western Australian Herbarium

https://florabase.dbca.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01062

Nuytsia 34: 255–260

Published online 26 October 2023

Eremophila improvisa, *E. rubicunda* and *E. saxatilis* (Scrophulariaceae), three new species from Western Australia

Andrew P. Brown[1,2] and Robert W. Davis[1]

[1]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[2]Corresponding author, email: watscu01@gmail.com

SHORT COMMUNICATION

Eremophila improvisa A.P.Br., *sp. nov.*

Type: Mount Padbury Station north-east of Karalundi, Western Australia, 10 June 2021, *J.D. Start & M.J. Start* 2101 (*holo*: PERTH 09578447; *iso*: CANB).

Illustration. A.P. Brown & B.J. Buirchell, *A field guide to the eremophilas of Western Australia*, *revised second edition* p. 323 (2021), as *E.* sp. Doolgunna.

A small much branched *shrub* 0.15–0.5 m high, 0.3–0.6 m wide. *Branches* grey to pale brown, terete, sparsely tuberculate, with an indumentum of short creamy white branched hairs when young, becoming glabrous with age. *Leaves* dark green, alternate, erect or spreading, clustered at ends of branches, sessile but gradually tapering to a short petiole-like base; lamina elliptic to oblanceolate, 5–15 mm long, 1.5–3 mm wide; upper and lower surfaces glabrous, tuberculate; margins entire; apex obtuse to acute. *Flowers* 1 per axil; pedicel straight or slightly curved, 2–5 mm long, with an indumentum of creamy white branched hairs. *Sepals* 5, brownish maroon, tinged green, 6–12 mm long, 1–2 mm wide, lanceolate, attenuate, separated at base, curving outwards apically, equal, not enlarging after flowering; outer surface with an indumentum of creamy white branched hairs; inner surface with an indumentum of creamy white branched hairs in distal third and more sparsely hairy below except along margins. *Corolla* zygomorphic, 14–18 mm long, 7–10 mm wide; outer surface purple to purplish red, unspotted, with an indumentum comprising a mixture of glandular hairs and rare short simple hairs; inner surface purple to purplish red, unspotted, glabrous towards anterior with an indumentum of matted simple hairs extending down from below medial section of lower and upper lobes; lobes subequal, spreading, obtuse. *Stamens* 4, included; filaments 7–9 mm long, glabrous; anthers glabrous. *Ovary* oblong, 5–7 mm long, 1.2–1.5 mm wide, glabrous; style eccentric, curved, 9–11 mm long, glabrous apart from some scattered simple hairs at base. *Seed* not observed. (Figure 1)

Diagnostic features. *Eremophila improvisa* may be distinguished from all other members of the genus by the following combination of characters: a small much branched shrub 0.15–0.5 m high; leaves green, alternate, glabrous, tuberculate; sepals lanceolate, attenuate, separated at base, appressed against the corolla, 6–12 mm long; corolla zygomorphic, outer surface purple to purplish red, unspotted, 14–18 mm long; ovary glabrous; style eccentric and curved.

© Department of Biodiversity, Conservation and Attractions 2023

ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

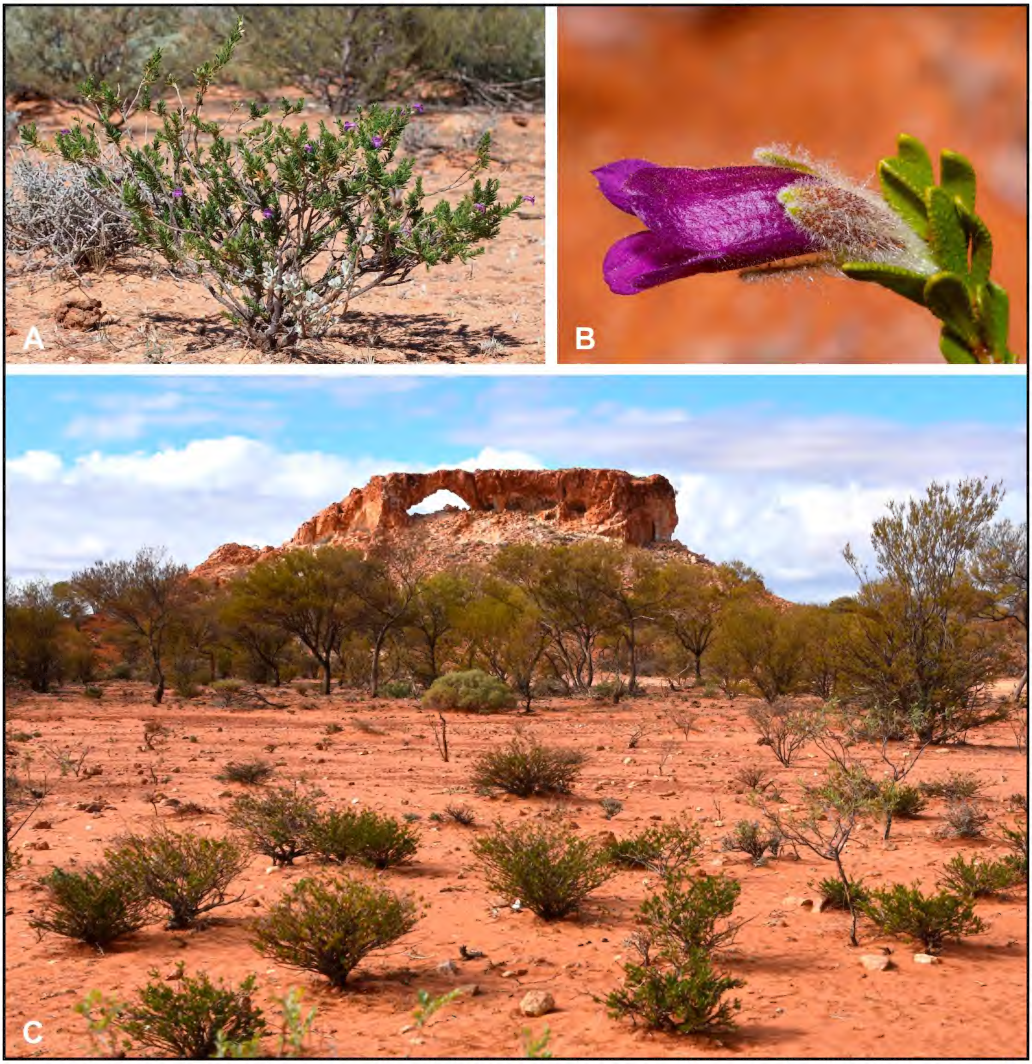

Figure 1. *Eremophila improvisa*. A – flowering plant; B – branch showing the dark green, glabrous, tuberculate leaves and flower with brownish maroon, green tinged sepals and purple to purplish red unspotted corolla; C – habitat showing *Eremophila improvisa* in the foreground. Photographs by A. Brown (A, C) and J. & J. Start (B), all from the type locality.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 10 June 2021, *J.D. Start & M.J. Start* 2102 (PERTH); 3 July 2021, *J.D. Start & M.J. Start* 2114 (PERTH).

Phenology. Flowering mainly between June and September.

Distribution and habitat. Known from a narrow geographic range north-east of Karalundi in the Murchison Bioregion (*sensu* Department of the Environment 2012), growing on a broad stony flat between rocky mesas with *Eremophila pterocarpa*, *Ptilotus obovatus*, *Senna artemisioides*, *Solanum lasiophyllum* and annuals (Figure 1).

Conservation status. To be listed as Priority One under Conservation Codes for Western Australian

Flora (Tanya Llorens, pers. comm.). The species is known from a single population that may be subject to grazing and future mining.

Etymology. The specific epithet is derived from the Latin *improvisus* (unforeseen or unexpected), in reference to the surprising, unexpected discovery of this new species when visiting the type location of *E. saxatilis* A.P.Br.

Affinities. *Eremophila improvisa* shares some morphological similarities with *E. anomala* Chinnock but is readily distinguished from that species by its more open habit, its smaller 6–12 mm long brownish maroon sepals (*cf.* 14–22 mm long and green in *E. anomala*) and its smaller 14–18 mm long purple to purplish red corolla (*cf.* 18–26 mm long and cream).

Eremophila rubicunda R.W.Davis, *sp. nov.*

Type: Landor Station, Western Australia, 25 June 2022, *R. Davis & A. Brown* RD 14075 (*holo*: PERTH 09484671; *iso*: CANB, MEL).

Eremophila sp. Landor (J. Start D7 33), Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 4 October 2023].

Illustration. A.P. Brown & B.J. Buirchell, *A field guide to the eremophilas of Western Australia, revised second edition* p. 329 (2021), as *E.* sp. Landor.

An erect *shrub* 1–2 m high, 1–2 m wide. *Branches* grey to pale brown, terete, with an indumentum of densely matted white simple hairs. *Leaves* grey-green, alternate, petiolate; lamina obovate to elliptical, 15–35 mm long, 6–19 mm wide; upper and lower surfaces with an indumentum of densely matted white simple hairs; margins entire; apex acuminate. *Flowers* 1 per axil; pedicel compressed, straight, 8–11 mm long, with an indumentum of densely matted white hairs. *Sepals* 5, dull red to grey-green, red suffused, straight or curved outwards apically, imbricate, unequal, not enlarging after flowering, posterior and anterior sepals with an indumentum of cobweb-like hairs on both surfaces; posterior sepal shortest in length, oblong to narrowly obovate, 10–10.5 mm long, 4.8–5.2 mm wide; anterior sepals narrowly obovate, *c.* 11 mm long, 3.7–4.1 mm wide; inner sepals longer than anterior sepals, narrowly obovate, 13–14 mm long, 4–4.2 mm wide, with an indumentum of cobweb-like hairs mostly along the central portion of outer surface but not on inner surface. *Corolla* zygomorphic, 25–30 mm long, 6–8.5 mm wide; outer surface red, unspotted, glabrous except for an indumentum of matted hairs on upper portion of tube; inner surface red with darker red spots on uppermost portion of tube, with an indumentum of matted hairs extending partially down tube at base of upper lobes and short thickened hairs extending fully down tube at base of lower lobes; lobes subequal, spreading, obtuse. *Stamens* 4, shortly exerted; filaments 15–20 mm long, glabrous except for some matted hairs at base; anthers glabrous. *Ovary* oblong to obovoid, 3–3.3 mm long, 1.8–2.1 mm wide, glabrous; style eccentric, curved, 25–28 mm long, glabrous except for some scattered simple hairs at base. *Fruit* obovoid, ribbed, 5–5.5 mm long, 4.2–4.5 mm wide, with a sparse covering of glandular hairs that are sometimes obscured by thick resin. *Seed* not observed. (Figure 2)

Diagnostic features. *Eremophila rubicunda* may be distinguished from all other members of the genus by the following combination of characters: an erect shrub to 2 m tall; sepals imbricate, unequal, oblong to narrowly obovate; leaves grey-green, upper and lower surfaces with an indumentum of densely matted white simple hairs; posterior sepal shortest, 10–10.5 mm long; corolla red, 25–35 mm long, with dark red markings in the throat of the tube; ovary glabrous; style eccentric and curved.

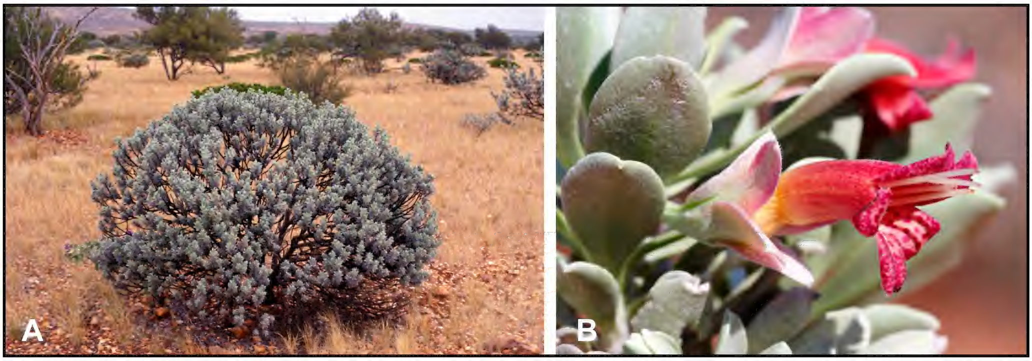

Figure 2. *Eremophila rubicunda*. A – plant and habitat; B – branch showing the grey-green leaves and flower with dull red to grey-green red suffused sepals and red corolla with darker red spots in the uppermost portion of the floral tube. Photographs by A. Brown from the type locality.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 25 June 2022, *R. Davis & A. Brown* RD 14076 (PERTH); 25 June 2022, *R. Davis & A. Brown* RD 14077 (PERTH); 1 July 2005, *D.J. Edinger* 5190 (PERTH); 11 Aug. 2005, *J. Start* D7 33 (PERTH).

Phenology. Flowering mainly between June and October.

Distribution and habitat. Known from one population north of Landor Homestead in the central west of the Gascoyne Bioregion (*sensu* Department of the Environment 2012). The population is large, consisting of several hundred plants on a stony rise growing with *Acacia* spp., *Eremophila flaccida*, *E. glutinosa*, *E. exilifolia*, *Ptilotus obovatus*, *P. schwartzii* and *Goodenia tenuiloba*.

Conservation status. Listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–) under the name *E.* sp. Landor (J. Start D7 33). The species is known from a single large population.

Etymology. The specific epithet is derived from the Latin *rubicundus* (red), in reference to the red-coloured flowers (Figure 2).

Affinities. *Eremophila rubicunda* shares some morphological similarities with *E. macmillaniana* C.A.Gardner but is readily distinguished from that species by its smaller habit 1–2 m high (*cf.* 1–4 m high), its shorter leaves 15–35 mm long (*cf.* 23–54 mm long), its smaller posterior sepal 10–10.5 × 4.8–5.2 mm (*cf.* 18–32 × 5–15 mm), its much shorter anterior and inner pairs of sepals 11–11.5 mm long and 13–14 mm long (*cf.* 16–30 mm long and 15–27 mm long), and its red corolla (*cf.* pink or cream).

Eremophila saxatilis A.P.Br., *sp. nov.*

Type: Mount Padbury Station north-east of Karalundi, Western Australia, 3 July 2021, *J.D. Start & M.J. Start* 2112 (*holo*: PERTH 09578439; *iso*: CANB).

Eremophila sp. Meekatharra (D.J. Edinger 4430), Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 4 October 2023].

Illustration. A.P. Brown & B.J. Buirchell, *A field guide to the eremophilas of Western Australia, revised second edition* p. 332 (2021), as *E.* sp. Meekatharra.

An erect spindly *shrub* 1–2.5 m high, 0.6–1.2 m wide. *Branches* grey-white to pale brown, terete, glabrous; new growth resinous. *Leaves* green, alternate, erect or spreading, clustered at ends of branches, sessile but tapering to a short petiole-like base; lamina rigid, obovate to widely elliptic, 4–7 mm long, 2–4 mm wide; upper and lower surfaces glabrous, resinous when young; margins serrate; apex obtuse to acute. *Flowers* 1 per axil; pedicel terete, curved downwards, 4–6 mm long, glabrous or with a sparse indumentum of short simple hairs. *Sepals* 5, green to brownish red, 4–6 mm long, 2–4 mm wide, ovate, attenuate, imbricate, initially appressed against the ovary then curving outwards apically, subequal, not enlarging after flowering; outer and inner surface glabrous, resinous. *Corolla* zygomorphic, 16–20 mm long, 8–12 mm wide; outer surface bluish mauve to mauve, unspotted, with a dense indumentum of simple hairs; inner surface cream to mauve, with scattered brownish-red spots below lobes, glabrous towards anterior with an indumentum of matted simple hairs extending down from below medial section of lower and upper lobes; lobes subequal, spreading, obtuse. *Stamens* 4, included; filaments 8–11 mm long, glabrous; anthers glabrous. *Ovary* oblong, 4–6 mm long, 2–2.5 mm wide, densely villous; style eccentric, straight, 10–13 mm long, glabrous apically with simple hairs at base. *Seed* not observed. (Figure 3)

Diagnostic features. *Eremophila saxatilis* may be distinguished from all other members of the genus by the following combination of characters: an erect spindly shrub 1–2.5 m high; new growth resinous; leaves green, sessile, alternate, obovate to widely elliptic, clustered at ends of branches; sepals 4–6 mm long, ovate, attenuate, imbricate, subequal, initially appressed against the ovary then curving outwards apically; corolla zygomorphic, 16–20 mm long; outer corolla surface bluish mauve to mauve, unspotted, with a dense covering of simple hairs; ovary densely villous; style eccentric and straight.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 16 July 2004, *D.J. Edinger* 4430 (PERTH); 1 Oct. 2000, *F. Hort, A. Grosse & J. Hort* 1178 (PERTH); 10 June 2021, *J.D. Start & M.J. Start* 2105 (PERTH); 10 June 2021, *J.D. Start & M.J. Start* 2106 (PERTH); 3 July 2021, *J.D. Start & M.J. Start* 2113 (PERTH).

Phenology. Flowering mainly between June and October.

Distribution and habitat. Known from a narrow geographic range north-east of Karalundi in the Murchison Bioregion (*sensu* Department of the Environment 2012), growing on the tops and slopes of rocky mesas with *Acacia* spp., *Dodonaea pachyneura* and *Ptilotus obovatus* (Figure 3).

Conservation status. Listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–) under the name *E.* sp. Meekatharra (D.J. Edinger 4430). The species is known from just two populations that may be subject to grazing and future mining.

Etymology. The specific epithet is derived from the Latin *saxatilis* (dwelling among rocks), in reference to the rocky habitat of the species (Figure 3).

Affinities. *Eremophila saxatilis* shares some morphological similarities with *E. pungens* Chinnock but is readily distinguished from that species by its resinous new growth (not resinous in *E. pungens*), its smaller leaves 4–7 × 2–4 mm (*cf.* 6–16 × 7–12 mm) which lack the recurved rigid apical spine that is usually present in *E. pungens*, its pendulous flowers (*cf.* held horizontally), its narrower sepals 2–4 mm

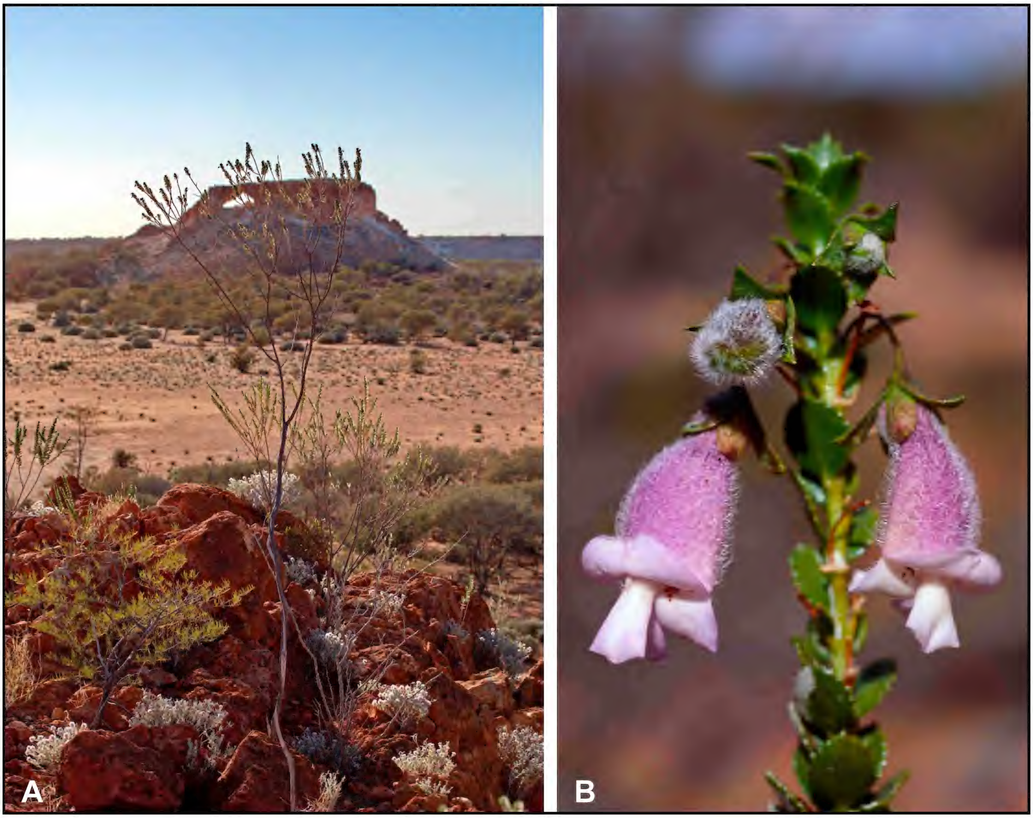

Figure 3. *Eremophila saxatilis*. A – plant showing its erect spindly habit; B – branch showing the green, glabrous, serrate margined leaves and pendulous flowers with green to brownish red, outwardly curved sepals and mauve, densely hairy corolla. Photographs by A. Brown from the type locality.

wide (*cf.* 3–8 mm) which are glabrous on both the upper and lower surfaces (*cf.* glabrous on upper surface and glandular-pubescent on the lower surface), and its shorter corolla 16–20 mm long (*cf.* 20–35 mm) which is covered with dense simple hairs on the outer surface (*cf.* glandular-pubescent).

Acknowledgements

We would like to thank Bevan Buirchell, Phil and Marlene James, and Joff and Joan Start who have often accompanied us in the field and who have made valuable comments during discussions about these species. We would also like to thank the Curator and staff at the Western Australian Herbarium for access to specimens and valuable edits to this paper.

References

Department of the Environment (2012). *Australia's bioregions (IBRA)*, IBRA7, Commonwealth of Australia. https://www.environment.gov.au/land/nrs/science/ibra [accessed 20 April 2023].

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dbca.wa.gov.au/ [accessed 4 October 2023].

Nuytsia The journal of the Western Australian Herbarium

https://florabase. dbca.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01060

Nuytsia 34: 261–294
Published online 26 October 2023

Four new species of *Triodia* (Poaceae) from the Pilbara and adjacent bioregions, Western Australia

Matthew D. Barrett[1,2,3,4,6], Pierre-Louis de Kock[5] and Steven J. Dillon[3]

[1]Australian Tropical Herbarium, James Cook University, McGregor Rd, Smithfield, Queensland 4878
[2]Kings Park and Botanic Garden, Department of Biodiversity, Conservation and Attractions,
1 Kattidj Close, Kings Park, Western Australia 6005
[3]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[4]School of Biological Sciences, The University of Western Australia, Crawley, Western Australia 6009
[5]dK Botanical, 6/11 Gibbon Street, Mosman Park, Western Australia 6012
[6]Corresponding author, email: matt.barrett@jcu.edu.au

Abstract

Barrett, M.D., de Kock, P.-L. & Dillon, S.J. Four new species of *Triodia* (Poaceae) from the Pilbara and adjacent bioregions, Western Australia. *Nuytsia* 34: 261–294 (2023). The Australian hummock genus *Triodia* R.Br. is currently undergoing taxonomic revision in light of new collections from surveys of remote Australia and increased resolution provided by molecular methods. This paper describes four new species of *Triodia* from the Pilbara and adjacent IBRA bioregions: *T. avenoides* M.D.Barrett, *T. degreyensis* M.D.Barrett, *T. karijini* M.D.Barrett & S.J.Dillon, and *T. lutiteana* M.D.Barrett & P.-L. de Kock. All four species are 'soft' spinifexes with elongate glumes and lemma lobes subulate to awned, and are only known from the Pilbara and adjacent Carnarvon and Gascoyne regions of Western Australia. *Triodia degreyensis* is known from a single range system in the north-eastern Pilbara. The taxon formerly known by the phrase name *T.* sp. Karijini (S. van Leeuwen 4111) is formally described here as *T. karijini*, and is restricted to mountains above 900 m altitude in the eastern Hamersley Range. *Triodia lutiteana* is only known from shale substrates north-west of Tom Price, and may be a polyploid species. The new species *T. avenoides* is segregated from *T. schinzii* (Henrard) Lazarides based on morphological and molecular differences and a disjunct distribution on sand sheets and dunes of the Carnarvon basin. The central Australian species *T. helmsii* (C.E.Hubb.) Lazarides is newly synonymised with *T. schinzii*, since no clear morphological or genetic differences between the two could be established. An amended description of *T. schinzii* is provided to accommodate these alterations to the species concept. Diagnostic character combinations for each species are given to allow discrimination from all other *Triodia* species. *Triodia degreyensis*, *T. karijini* and *T. lutiteana* are known from between one and four localities, and have priority conservation statuses, while *T. avenoides* and *T. schinzii* are not considered threatened. With the species described here, a total of 29 species and one hybrid are now known from the Pilbara bioregion and its immediate surrounds.

Introduction

Triodia R.Br. hummock grasses are restricted to mainland Australia, where they are characteristic components of many arid and semi-arid communities. The genus currently consists of 83 described and accepted species (Lazarides 1997; Lazarides *et al*. 2005; Armstrong 2008; Barrett & Barrett 2011,

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

2015; Hurry *et al.* 2012; Crisp *et al.* 2015; Anderson *et al.* 2017a; Barrett & Trudgen 2018; Barrett 2019). However, a further 21 putative undescribed species are listed using phrase names in the state checklists of Western Australia (7 species; https://florabase.dbca.wa.gov.au, accessed 19 Aug. 2021) and the Northern Territory (14 species; http://eflora.nt.gov.au/, accessed 19 Aug. 2021). *Triodia* is undergoing systematic revision in the light of intensive botanical survey in remote Australia and new molecular phylogenetic data, as exemplified by the molecular and morphological investigations of Anderson *et al.* (2016; 2017a, b; 2019) for the *T. basedowii* E.Pritz. complex. A phylogenetic overview of *Triodia* was provided by Toon *et al.* (2015); however, names and distributions used in that paper should be used with caution given recent and on-going taxonomic changes in the genus. The current paper treats four taxa of 'soft' spinifex with epistomatous leaf blades (see Toon *et al.* 2015; Barrett 2019) and lobed to awned lemmas (Schinzii or Pungens groups *sensu* Lazarides 1997) from the Pilbara and adjacent IBRA bioregions (Department of Environment 2013). Two of the new species are morphologically similar to *T. schinzii* (Henrard) Lazarides, while the other two are both morphologically similar to *T. melvillei* (C.E.Hubb.) Lazarides, *T. pisoliticola* Trudgen & M.D.Barrett and *T. veniciae* M.D.Barrett. The taxonomic changes effected here (four new species and a synonym) bring the total number of described and accepted *Triodia* species to 86.

Triodia schinzii has long been considered a widespread species occurring throughout much of arid Australia, where it is common on red sand dunes and deeper sand swales. In the course of reviewing *Triodia* type specimens, and as part of a concurrent intensive review of the variation in Pilbara *Triodia*, two anomalies were detected relating to *T. schinzii*: (1) in central Australia, no clear distinction could be found between *T. schinzii* and *T. helmsii* (C.E.Hubb.) Lazarides; and (2) a western disjunct population of *T. schinzii* was found to be morphologically and genetically distinct. Consequently, *T. helmsii* is synonymised with *T. schinzii*, and a new species, *T. avenoides* M.D.Barrett, is segregated from *T. schinzii*.

In 2010, a specimen (PERTH 008365547) of an unusual spinifex was collected from a high mountain in the eastern Hamersley Range by Jerome Bull and flagged as unusual by one of us (SJD). It was subsequently determined to be morphologically discrete from all known species of *Triodia*, several additional matching collections from nearby mountains were located filed under *T. melvillei*, and the taxon was formally listed using the phrase name *T.* sp. Karijini (S. van Leeuwen 4111). DNA sequences from the ITS and ETS regions confirmed that the collections from mountains formed a novel lineage (M.D. Barrett, unpublished data), remote from *T. melvillei* and closer to *T. pisoliticola*. *Triodia* sp. Karijini (S. van Leeuwen 4111) is here formally described as a new species, *T. karijini* M.D.Barrett & S.J.Dillon.

In 2012, a population of *Triodia* from near the De Grey River was located by one of us (MDB) on gravelly slopes, co-occurring with *T. schinzii*. Although initially attributed to *T. bitextura* Lazarides *s. lat.*, unpublished molecular data placed it closer to *T. avenoides*, which was corroborated by glume nerve number (7–13, similar to *T. avenoides*, rather than 3–5 as in *T. bitextura*). The new population differed from *T. avenoides* in plant height, a broadly acute to shortly pungent callus (long-pungent callus in *T. avenoides* and *T. schinzii*), glumes shorter or subequal to the spikelet (glumes usually longer than the spikelet excluding awns in *T. avenoides* and *T. schinzii*), hairy palea (glabrous or rarely hairy in *T. avenoides* and *T. schinzii*), and by substrate preference. This taxon is here described as a new species, *T. degreyensis* M.D.Barrett.

In 2017, during surveys in the Nammuldi-Silvergrass area north-west of Tom Price by P.-L. de Kock, then at Biota Environmental Sciences, an unusual *Triodia* was found forming monocultures on small shale hills. This taxon was subsequently listed on the WA census under the phrase name *T.* sp. Silvergrass (P.-L. de Kock BES 00808). The lemma lobes of this form are similar to those of *T. karijini* and *T. veniciae* in being acuminate but not produced into awns. Although morphologically similar to *T. veniciae*, which is also restricted to shale substrates, the sheath submarginal surfaces of *T*. sp. Silvergrass differ in having long and densely woolly hairs, compared to the glabrous or straight-hairy surfaces of *T. veniciae*. Comparisons of ITS and ETS sequences indicated a close relationship with *T. karijini*, which differs in having a much smaller stature, different sheath hairs, longer lemma mid-lobe, shorter ligule and is restricted to banded iron formation (BIF) substrates on mountains above 900 m. Accordingly, it is described here as a new species, *T. lutiteana* M.D.Barrett & P.-L.de Kock, and incomplete evidence consistent with the possibility of a polyploid origin is discussed.

All of the new species, except *T. lutiteana*, are covered in the multi-access Lucid identification app for Pilbara *Triodia*, SpiKey (Barrett *et al*. 2017).

Methods

Morphological methods follow those of Barrett *et al*. (2017), Barrett and Trudgen (2018) and Barrett (2019), except as discussed below. Measurements were made to the nearest 0.5 mm, unless indicated more precisely.

Leaf anatomy was assessed by sectioning fresh or dried leaves with a double-sided razor blade after soaking in hot water with a small amount of detergent. Leaf anatomy was classified as epistomatous or amphistomatous, following previous definitions (see Toon *et al*. 2015; Barrett 2019). Amphistomatous leaf blades have a more or less equal number of stomatal grooves on the abaxial and adaxial surfaces, the grooves evenly spaced over each surface, and in section the grooves surrounded by green chlorenchyma tissue and bundle sheath cells, reducing the colourless spongy mesophyll cells to small ribs between the vascular bundles. Amphistomatous leaves typically have well-developed sclerenchyma below the epidermis, and leaves are usually rigid and needle-like; they are colloquially known as 'hard' spinifexes (e.g. Gamage *et al.* 2012, Fig. 2b). Epistomatous leaf blades lack stomatal grooves on the lateral abaxial faces, in section also lacking chlorenchyma and bundle sheath cells that would typically (in amphistomatous leaves) surround each stomatal groove; the corresponding space is instead occupied by large areas of colourless spongy mesophyll in section (e.g. Gamage *et al.* 2012, Fig 2a; Fig. 1J here). Species with epistomatous leaves typically have a thin layer of sclerenchyma tissue below the epidermis, and the blades are consequently usually more flexible at least when fresh; they are colloquially known as 'soft' spinifexes (e.g. Gamage *et al.* 2012). The terms epistomatous and amphistomatous are used in preference to, but are synonymous with, 'soft' and 'hard' terminology sometimes applied to leaf anatomy prior to Toon *et al.* (2015). Lemma lobes are measured from the deepest point of sinus (both sides measured if asymmetrical), as used by Barrett *et al*. (2017).

Species of the genus *Triodia* are often called *hummock grasses*, for the tendency of culms to form above ground-level, with clusters of leaves and short shoots appearing to be heaped on each other in a tight to loose pile. This *hummock* characteristic is in contrast to many perennial grasses with rhizomes at or below the soil surface, producing tufts of leaves arising near ground level, the resulting architecture termed a *tussock*. Very young *Triodia* plants can appear somewhat like a tussock, but usually soon develop the distinctive hummock form; although the distinction is not always clear-cut, the term hummock is typically applied to *Triodia*, regardless of its exact form. However, in a few *Triodia* species, such as *T. karijini* described here, even mature and old plants produce leaves and short shoots arising in a dense tuft from ground level, with the wiry rhizomes and internodes at ground level, in a typical tussock form. Such plants are here referred to as *hummocks with a tussock form*, to both retain homologous connection with typical *Triodia* plants, but to emphasise the form difference in these species.

A clarification of inflorescence axis terminology is required to precisely describe different orders of branching. The term *rachis* is frequently used for plant inflorescence axes, and in grasses is often used for any axis to which spikelets are attached (Sharp & Simon 2002), which does not allow easy distinction between primary and secondary axes. Lazarides (1970; 1997) did not use the term rachis in *Triodia* and other grasses, but instead referred to axes of the inflorescence, especially for the 'main stem' of the inflorescence, but also to refer to the branches of a panicle. Here we slightly modify Lazarides' terminology and use the term *primary axis*, with *primary branches* diverging off the primary axis. To avoid confusion, the terminology *axis of the primary branches* is used rather than 'secondary axes'. Where the primary branches are further divided (nearly always once-divided, if at all), the inflorescence is referred to as ternate. Characters used to describe the inflorescence branches include *longest primary branch length* (from its divergence from the primary axis to the apex of the intact spikelets, following the longer branch if ternate; measuring three longest branches per specimen); *number of spikelets on longest primary branches* (ignoring the shorter branches if ternate; three measurements per specimen), and *internodes between pedicels on longest primary branches* (measured on three longest lower branches per specimen).

Pedicels typically decrease in length along a panicle branch, while the terminal 'pedicel' (the continuation of the branch axis) is frequently longer than all lateral pedicels. The basic architecture makes pedicel length an extremely variable character. In order to tighten the definition of pedicel length used by Lazarides (1997), the terminal pedicel length is reported separately, while only the longest lateral pedicels at the base of longest primary branches were measured as a character, termed *longest pedicels at base of longest panicle branches*. Care was taken to identify and exclude short ternate branches, which can occur near the base of long primary branches and may have only two spikelets, which can lead to a terminal pedicel in a short branch being mistaken for a long lateral pedicel. Three terminal pedicels per primary branch and *longest pedicels at base of longest panicle branches* were measured per specimen. In species with few specimens available for descriptions, up to 10 units were measured for each branch and pedicel character per specimen, to better capture the range of variation.

Flow cytometry of two species (see notes under *T. lutiteana* for reference samples) was performed using the methodology of Anderson *et al.* (2017b).

All specimens cited were viewed (at least by MB), except for some duplicates indicated accordingly (*n.v.*).

Results and Discussion

Review of the taxonomic concept of T. schinzii

Plectrachne schinzii Henrard (now *T. schinzii*) was first described by Henrard (1929) as the type species of his new genus *Plectrachne* Henrard, based on a G.F. Hill collection from Lander Creek (now Lander River) in central Northern Territory. Hubbard (1941) later described *Plectrachne helmsii* C.E.Hubb. (now *T. helmsii* (C.E.Hubb.) Lazarides) as a new species from Everard Range, also in central Australia. In the protologue, Hubbard (1941) specifically compared *T. helmsii* to *Plectrachne pungens* (R.Br.) C.E.Hubb. (now *T. bitextura* Lazarides), differing by the longer glumes and lemmas, and a membranous palea (by inference compared with the shorter glumes and lemmas, and partially indurated palea, in *P. pungens*). However, no mention was made by Henrard (1941) of any similarity of *P. helmsii* to *P. schinzii*, despite a closer geographical proximity and more similar glume length (than to *T. bitextura*). *Triodia helmsii* and *T. schinzii* are more recently described as differing in few and subtle characters (e.g. Lazarides *et al.* 2005). This prompted a review of whether *T. helmsii* could actually be a synonym of *T. schinzii*.

Lazarides (1970), in treating the grasses of Central Australia, also did not compare the two species, since *T. helmsii* was not treated there. The first time that *T. schinzii* and *T. helmsii* were directly compared was in the Gramineae treatment (as *Plectrachne*) for Flora of Central Australia (Lazarides 1981), wherein *P. helmsii* was differentiated from both *P. schinzii* and *P. pungens* (now *T. bitextura*) by 'Palea membranous throughout; rhachilla between glumes with tooth-like projection; glumes subequal or lower much shorter', compared to 'Palea coriaceous in lower half to two-thirds, abruptly hyaline above; rhachilla [sic] without a projection; glumes subequal' in the other two species. The relative glume length is an inconstant feature, while the rachilla projection was later noted as only being present in the type specimen of *T. helmsii* (Lazarides 1997) and is therefore at least inconstant and may even be a singleton aberration, since it has not been observed in other specimens. Lazarides (1997) added an anther length difference (2–2.8 mm in *T. helmsii*, 3–4 mm long in *T. schinzii*). Lazarides *et al.* (2005) utilised a different character to separate *T. schinzii* (from many others, including *T. helmsii*): 'Pedicels of terminal spikelets much longer than those of the lateral ones (up to 20 mm, versus about 2 mm)' in *T. schinzii*, compared to 'Pedicels usually variable in length (but not in the consistent pattern described above), or of similar length and all short' in *T. helmsii* (and others). However, in the text Lazarides *et al.* (2005) stated that *T. helmsii* differs from *T. schinzii* 'by its uniformly textured palea and smaller spikelets'. In treating the grasses of South Australia, Jessop *et al.* (2006) specifically followed Lazarides (1997) for their treatment of *T. helmsii*, with only slight clarification in their key compared to Lazarides (1997): 'Palea uniformly membranous or hyaline; anthers 2–2.8 mm long' in *T. helmsii*, compared to 'Palea cartilaginous or hardened in the lower part (usually about three-quarters), abruptly hyaline above; anthers 2.5–4 mm long' in *T. schinzii*. Spikelets (excluding awns, and implicitly excluding glumes, since spikelet measures were shorter and glumes stated to exceed spikelets) were reported to be 11–15 mm long in *T. helmsii*, and 10–30 mm long in *T. schinzii* by Lazarides (1997). Lazarides *et al.* (2005) reported slightly different lengths: 12–21 mm long in *T. helmsii*, and 10–30 mm long in *T. schinzii*; however, the measurement for *T. helmsii* is identical to their reported glume length, and almost certainly this was intended to include glumes, presumably standardising 'spikelet length' to include glumes across the Flora, although the same was not done for *T. schinzii*, since their cited spikelet lengths match Lazarides (1997) spikelet length (implicitly excluding glumes) rather than glume length in same. In either case spikelet length difference is also therefore predominantly overlapping and cannot be used to discriminate *T. helmsii* from the more variable *T. schinzii*. In the dichotomous key to *Triodia* of Sharp and Simon (2002), *T. helmsii* (along with *T. acutispicula* Lazarides) is separated by 'Body of lemma at least 4.5 mm long [later more specific, 4.5–5 mm long]' from *T. schinzii* (and others) by 'Body of lemma up to 3 mm long'. However, this difference must be based on incomplete data, since Lazarides (1997) had previously described the lemma body of *T. helmsii* as '4.5–6.5 mm long (body and callus)', which includes a callus '1–1.5 mm long', and that of *T. schinzii* as 3–6(–9) mm long (without stating whether that included the 1–1.5 mm long callus). There is therefore very broad overlap in lemma body length between *T. helmsii* and *T. schinzii*. From these works, only four characters seem to be potentially or partially diagnostic: (1) pedicel length differences, (2) spikelets 11–15 mm long in *T. helmsii*, versus 10–30 mm long in *T. schinzii*; (3) anther length 2–2.8 mm in *T. helmsii*, versus 3–4 mm long in *T. schinzii*; and (4) palea membranous in *T. helmsii*, versus bitextured (i.e. both indurated and membranous) in *T. schinzii*. Note that all *T. schinzii* measurements cited by previous authors include both *T. avenoides* and *T. schinzii s. str.* as separated in this paper, requiring re-measurement of all taxa. The same specimens of *T. helmsii* were cited by Lazarides (1997) and Lazarides *et al.* (2005); only a subset of these *T. helmsii* specimens were examined here: *Beauglehole* 60786, *Beauglehole* 60601, *Dunlop* 1916, and the type *Helms* s.n. (see under *T. schinzii* for full citation). The specimen *George* 8387 was also listed under *T. helmsii* by Lazarides (1997), but on examination was found to have a bitextured palea, placing it in *T. schinzii*, so is discussed under the latter species. In all specimens the most mature florets available were examined, to minimise developmental artefacts to the extent possible. Anther and palea observations in particular can only be conducted on one or a few spikelets per specimen, and they vary with maturity; consequently different results can be obtained from the same specimen simply through dissecting different florets. Consequently, for *T. helmsii*, measurements by Lazarides were also included in character ranges for that species (although they differed only slightly from measurements made for this study), with the exclusion of the doubtful spikelet length in Lazarides (2005) discussed above. Pedicel lengths were defined as described in the methods, in order to delimit a character with lower variance than used by Lazarides (1997).

Observations on these characters with a range of collections found:

(1) Pedicel length cannot be reliably used to discriminate *T. helmsii* relative to *T. avenoides* or *T. schinzii*. Longest pedicels at base of longest panicle branches were (2.0–)4.0–15.0 mm long in *T. avenoides* and (1.0–)1.4–8.5 mm long in *T. schinzii*, while terminal pedicels were 9.5–34.0 mm long in *T. avenoides* and 8.0–32.0 mm long in *T. schinzii*. In the type of *T. helmsii*, the longer basal lateral pedicels were 1.0–4.8 mm long, and terminal pedicels 7.0–15.5 mm long. In all three taxa, the terminal pedicels were consistently longer than the lateral pedicels, and considerable variation was observed in lateral pedicel length, even when restricted to the longer basal pedicels (not all lateral pedicels measured by Lazarides). Although there is some tendency toward shorter pedicel lengths in the type (at least) of *T. helmsii* relative to *T. avenoides* and *T. schinzii*, lengths show considerable overlap between the three taxa, and almost complete overlap of *T. helmsii* (type specimen) with the lower end of the range of both *T. avenoides* and *T. schinzii*. Furthermore, all examined specimens of *T. helmsii* are incompletely mature (see (3) and (4) below), which may contribute to their smaller dimensions.

(2) Spikelet lengths could not discriminate between *T. helmsii* and *T. schinzii s. str.*, as their ranges almost complete overlap. This is partly complicated by some uncertainty whether only the combined florets were measured (excluding glumes, which are usually longer than the combined florets) in Lazarides *et al.* (2005), while spikelet measurements in Lazarides (1997) implicitly exclude glumes, by reporting spikelet lengths shorter than glume lengths and that glumes exceed spikelets. The combined florets, without glumes, were here found to be 8.5–13 mm long in *T. avenoides* and (6–)7.5–19 mm long in *T. schinzii*, compared with 11–15 mm in *T. helmsii* (agreeing with Lazarides 1997, but not Lazarides *et al.* 2005, which is presumably an error, see earlier discussion). The fact we could not find combined florets exceeding 20 mm suggests that the upper range of spikelet length reported by Lazarides (1997) for *T. schinzii* (to 30 mm long) does include glume length. Either way, there is nearly complete overlap between *T. helmsii* and *T. schinzii s. str.* in combined floret length. If the 'spikelet' measurement includes glumes, then glume length would actually be the determining criterion in these species with glumes longer than the combined florets. Glume lengths were here found to be (12.5–)15–30 mm in *T. avenoides*, (12–)14–26 mm in *T. schinzii s. str.* and 12–21 mm in *T. helmsii*; these values are again completely overlapping.

(3) Anther length overlapped more than reported by Lazarides (2–2.8 mm long in *T. helmsii*, versus 3–4 mm long in *T. schinzii*). Anthers were here found to be 2.3–4.4 mm long in *T. avenoides*, 2.0–3.8 mm long in *T. schinzii*, and 2.0–2.8 in *T. helmsii*. Anthers present on specimens span a range of developmental conditions, and unless exserted and dehisced cannot be easily recognised as mature or immature. Exserted anthers are soon deciduous, and not often present on specimens. Consequently, reported ranges of anthers in *Triodia* are

expected to include immature anthers at the lower end. The anthers in specimens of *T. helmsii* observed here appeared to be immature, and this likely also applies to measurements made by Lazarides (1997), who examined the same specimens and only a few additional ones, although the exact anthers (and paleas) examined by Lazarides can never be determined. The immaturity of the anthers may thus have biased the range of lengths reported by Lazarides (1997). In *T. schinzii*, anthers as small as 2.0 mm long were regularly observed from non-basal florets, and occasionally in basal florets, although their maturity is unknown. In conclusion, although the measured *T. helmsii* anther length is consistently within the lower end of the range in *T. schinzii*, there is very broad, or even complete, overlap in measured anther length between *T. schinzii, T. avenoides* and *T. helmsii*, and the difference in range extremes is likely developmental.

Note that although many grasses produce cleistogamous flowers, usually with smaller anther size than chasmogamous flowers, no such condition has yet been observed in *Triodia*, and as far as is known, all *Triodia* species are chasmogamous and exsert their anthers at maturity (Thompson 2021; M.D. Barrett, pers. obs.). It is therefore unlikely, but not impossible, that *T. helmsii* represents a cleistogamous form of *T. schinzii*.

(4) The reported palea texture difference is likely an artefact of maturity; immature paleas of *T. schinzii* can be uniformly textured, while available specimens of *T. helmsii* are at least incompletely mature. The palea of the basal floret in mature specimens (those with florets turgid and diverging from the rachilla axis, not obviously under-developed anthers and styles, some rachillas beginning to fragment, and/or some florets with exserted anther filaments) of *T. schinzii* and *T. avenoides* was always bitextured, and usually distinctly so, as described by Lazarides (1997). A similar condition was observed in *A.S. George* 8387 (PERTH), which has an immature inflorescence, and was cited by Lazarides (1997) under *T. helmsii*, but has a bitextured palea, so belongs in *T. schinzii* following Lazarides' characters. In *T. schinzii*, the demarcation of the two textures in the palea is more diffuse than that of the lemma, and occasionally paleas are more obscurely bitextured even in well-developed florets, especially when the membranous upper part was small (*c.* 0.5–0.7 mm long), blurring the line between bitextured and uniformly textured palea.

In *T. schinzii* specimens with immature spikelets (identified as those with even the most mature florets not yet swelling, turgid or becoming loose from each other and/or, anthers and styles scarcely developed), a range of somewhat intermediate development and texture conditions were observed. For example, *Barrett & Anderson* 4072 and *George* ASG 3454 (both PERTH) had a clearly bitextured palea with truncate membranous apex, but scarcely indurated lower part, the demarcation due to a sharp change in colour and translucency. In *Mathews & Orifici* BES BDM 032 (PERTH) the palea was bitextured, with a sharp transition line, the upper and lower parts differing in both colour and texture. However, in *D. Pearson* DJP712, *K.F. Kenneally* 9852 and *Y. Power* 186 (all cited by Lazarides 1997 under *T. schinzii*; both with immature inflorescences; PERTH duplicates examined) the palea was found to be entirely membranous, with only a gradual change in colour between brown lower half and upper translucent *c.* 1/4 – these paleas may have developed into a more obviously bitextured condition with maturity. A specimen of *T. schinzii* from 50 miles east of Docker Settlement (*Latz* 830, PERTH, DNA, CANB; not cited by Lazarides (1997) or Lazarides *et al.* (2005)) had smaller spikelets and florets than other examined specimens, but had a clearly bitextured palea in the lowermost floret, with a distinct membranous upper third. The second-lowest (and less mature) palea in this specimen was scarcely bitextured at all, with an obscurely

> indurated (almost chartaceous) lower part, and a membranous apex, with a very diffuse boundary between them (very similar to the condition in *T. helmsii*, see below). This serves as an example of a developmental series in *T. schinzii*, from immature very weakly bitextured to strongly bitextured palea; the same transition from uniform to bitextured also occurs in both the lemma and palea of other species with bitextured lemmas (e.g. *T. basitricha*, *T. bitextura*; M.D. Barrett, pers. obs., which require mature florets for accurate discrimination from species lacking a bitextured lemma such as *T. bynoei* C.E.Hubb.).
>
> Examination of the palea in the type of *T. helmsii* did not reveal any clear division in texture, but the palea had a membranous apex gradually thickening toward the chartaceous base, i.e. was weakly 2-textured but lacked a sharp demarcation line; this is the same condition observed in immature florets of *T. schinzii*. All examined specimens determined as *T. helmsii* by Lazarides (1997), including the type (*Helms s.n.*; see under *T. schinzii* for duplicates examined) appear to be immature, as evidenced by the fact that even the most developed florets showed no signs of having exserted any of their anthers, and frequently had very poorly developed anthers and styles. The lemma bitexture line was never callused on the reverse side in any of the *T. helmsii* specimens, similar to immature *T. bitextura* and *T. schinzii*, while a callused reverse side of the bitexture line is present in mature lemmas of all other species with a bitextured lemma. Furthermore, in the examined *T. helmsii* specimens nearly all florets remained tightly appressed to each other, not becoming turgid and diverging in angle as in mature spikelets. The florets in examined *T. helmsii* specimens are therefore here interpreted as developmental stages prior to full formation of the bitextured lemma, and it can be expected that the palea will be similarly underdeveloped, as observed in some *T. schinzii*.
>
> Although the palea difference between the most common mature condition in *T. schinzii* (and *T. avenoides*) and the few (immature) specimens of *T. helmsii* studied by Lazarides is stark on first encounter, it is clear that *T. helmsii* has been described based on incompletely mature specimens, and when compared with a range of developmental material of *T. schinzii*, the range of palea variation is completely overlapping.

Since all characters previously indicated as distinguishing *T. helmsii* from *T. schinzii* (*s. lat.*) show almost complete overlap, their separation cannot be supported on morphological grounds.

DNA sequencing of ITS and ETS regions of ribosomal DNA (Toon *et al.* 2015; M.D. Barrett, unpublished data) showed no consistent difference in ITS between *T. helmsii* and *T. schinzii* samples (e.g. in the Toon *et al.* 2015 Supplementary data 3.3 ITS tree, *T. schinzii* 9773 is identical to *T. helmsii* 60601 (and also to *T. salina* 8814; the identity of this *T. salina* specimen requires investigation, since the ITS sequence does not match other *T. salina* specimens, M.D. Barrett unpublished data); note that their divergent *T. schinzii* 9722 is here placed under the new species *T. avenoides*). The *mat*K tree of Toon *et al.* (2015, Supplementary data 3.4) places their *T. helmsii* sample identical to 9722 and in the same clade as *T. salina* 8814, rather than *T. schinzii* 9773, with low support, and little variation between species. In addition, chloroplast loci must be interpreted with caution, since chloroplast capture has been observed in *Triodia*, while nrDNA exhibits considerably less introgression (Anderson *et al.* 2016; M.D. Barrett, unpublished data). Ribosomal DNA phylogenies show that the *T. helmsii* sample is very close to, if not identical with, *T. schinzii*. However, ribosomal DNA is not always sufficient to distinguish between closely related species (e.g. Lee *et al.* 2007; Hammer *et al.* 2018).

Geographically, the distribution of *T. helmsii sensu* Lazarides *et al.* (2005) (central WA and southern NT, into northern SA) overlaps almost entirely with *T. schinzii*. At least one of the specimens attributed to *T. helmsii* (5 miles east of Docker Settlement, *Dunlop* 1916, CANB, DNA) was collected from within a large, continuous, undifferentiated population (P.K. Latz, pers. comm.), from which all other collections (*Albrecht* 9668 (NT), *Latz* 22930 (NT), and *Anderson* BMA 86 (PERTH)) are attributed to *T. schinzii*. Distribution therefore cannot be used to differentiate *T. helmsii* and *T. schinzii*.

Both *T. helmsii* and *T. schinzii* primarily occur on the same substrate, red sand dunes, deep red sands, or occasionally on red sandy loam, and are not obviously ecologically separated. *Triodia schinzii* can occasionally occur on sand overlying or adjacent to rocky substrates, and these are presumably responsible for the rock-based substrates included in Lazarides' (1997) habitat description 'Chiefly on plains, dunes, sandhills, swales and pindan in deep, red sands, sandy loams, clayey sands and sandy red earths; also on shallow stony soils, alluvial creek levees, coastal pindan and beach sands; associated with sandstone, laterite, limestone and slates.' Lazarides' (1997) reported the habitat for *T. helmsii* as 'Skeletal rocky hillslopes; also on sand dunes and plains in red sands and sandy loams', and the same wording was rehashed by Lazarides *et al.* (2005) and Jessop *et al.* (2006). All three references thus include 'rocky slopes' among the habitat for *T. helmsii*; however, we were unable to locate any specimen determined as *T. helmsii* (by Lazarides or anyone else) that did not describe the habitat as some variant of sand, sand dunes or sandy loam, nor any that mention a rocky slope. Substrate was not mentioned in the protologue (Hubbard 1941), so it is unclear where Lazarides' reference to rocky slopes originated. The collection *Vonow et al.* 3098 (DNA, PERTH), described from '[Pangkupirri] Rockhole, Walter James Range, c. 200 m E from rockhole' was determined as *T. helmsii*, but is *T. melvillei* (an AD duplicate numbered *Vonow et al.* 3098 B has not been seen by us, but likely also represents *T. melvillei*, since all '3098' were initially determined as *T. helmsii* by D. Symon); however this collection was made in 2006, so it did not contribute to the habitat descriptions discussed above.

The lack of clear morphological and genetic distinction between *T. schinzii* and *T. helmsii*, coupled with overlapping geographic distributions and habitats suggests they belong to a single taxon. They are synonymised here under the older name, *T. schinzii*. It is concluded here that *T. helmsii* represents slightly immature specimens at the diminutive extreme of variation in *T. schinzii*.

In contrast to the broadly overlapping distributions of *T. schinzii* and *T. helmsii* in central Australia, populations of *T. schinzii* on sand dunes and plains in the Carnarvon Basin at the western-most range of *T. schinzii* are disjunct from those of sand deserts to the east, with the rocky Pilbara ranges forming a biogeographic barrier. Comparison of morphological features revealed several consistent differences between plants in the two disjunct areas (east and west of the Pilbara), in particular the widths of lemmas and glumes are non-overlapping, or scarcely overlapping, respectively. DNA sequencing of the ITS and ETS region (Toon *et al*. 2015; M.D. Barrett, unpublished data) from representative samples from the two disjunct regions revealed the presence of two clades corresponding to the two morphological forms, (e.g. in the Toon *et al*. 2015 Supplementary data 3.3 ITS tree, *T. schinzii* 9773 from central Australia, representing *T. schinzii s. str.*, is divergent from *T. schinzii* 9722 representing *T. avenoides*, with the former supported as closer to other species such as *T. pungens* by posterior probability >0.95, although bootstrap support was <80%). Since these two molecular clades can be defined by consistent morphological differences, they are considered to represent two allopatric species. The western form of *T. schinzii* is described here as a new species, *T. avenoides*.

Triodia schinzii as treated here remains similar to the core concept of Lazarides (1997). Alterations to the range of some character states were made to accommodate *T. helmsii* and the removal of the western populations, described below as *T. avenoides*. A revised description of *T. schinzii* is therefore also provided.

Genome size and ploidy estimation in T. lutiteana

Ten plants from a single population of *T. lutiteana* were measured for genome size (voucher *P.L. de Kock* 1108) and found to have 8.37 ± 0.06 pg 2C DNA (mean ± s.d.). This genome size is the largest of any *Triodia* measured to date (more than 2500 *Triodia* individuals have been measured, representing over 400 populations and more than 50 species; M.D. Barrett, unpublished data). *Triodia lutiteana* had approximately 3.3 times as much DNA as the related *T. pisoliticola* reference (2C value of 2.55 ± 0.08 pg, inferred diploid, voucher *M.D. Barrett* 4546, PERTH 08618836), the most closely related species measured for genome size. *Triodia karijini* has not been accurately measured, but measurements from seeds extracted from one plant (voucher *M.D. Barrett* MDB 4475, PERTH 08776253) were approximately 2.5 pg 2C, close to the diploid value for *T. pisoliticola*. *Triodia pisoliticola*, as a close relative rather than an ancestor, can only be used as an approximation of the ancestral DNA content of *T. lutiteana*, and chromosome counts are required to accurately determine its ploidy. Nevertheless, the sampled population of *T. lutiteana* is uniformly composed of, or at least dominated by, highly polyploid individuals, likely either hexaploids or octoploids. Since higher ploidy is often associated with larger plant dimensions (e.g. Rios *et al*. 2015), a high ploidy level is consistent with the more robust habit and taller inflorescences observed in *T. lutiteana* relative to its apparent closest relatives *T. karijini* and *T. pisoliticola*. Given the restricted distribution of *T. lutiteana*, it is possible that the entire species is polyploid (hexaploid or octoploid).

Taxonomy

Triodia avenoides M.D.Barrett, *sp. nov*.

Type: Uaroo Station, *c*. 5 km west of Uaroo Turnoff on North West Coastal Highway, West Pilbara region, Western Australia, 22 March 2013, *M.D. Barrett & B.M. Anderson* MDB 4121 (*holo*: PERTH 08776261; *iso*: CANB).

Triodia sp. Nanutarra (S. van Leeuwen 5037) Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Hummock-forming *perennial*, resinous at least on leaf blades, not obviously stoloniferous (stolons mostly shorter than the hummock margins); *hummocks* compact, 40–70 cm high, 50–150 cm wide; *flowering culms* 120–150 cm high. *Vegetative culm internodes* all short, 0.4–4.0 cm long, obscured by subtending foliage, dull red-brown, glabrous or minutely hairy with appressed short white hairs; aerial roots absent or few and short, up to 5 cm long. *Leaf sheaths* 2.8–7.6 cm long, 2.1–4.0(–6.0) mm wide near apex, glabrous on surfaces and lateral margins, resinous or not, straw-coloured, obscurely to prominently nerved especially near margins; margins glabrous; margins of *orifice* ±truncate to shortly auriculate with auricle up to 0.3 mm long, with a dense fringe of hairs, the longest hairs 0.5–4.0 mm long. *Ligule* a dense fringe of hairs 0.4–0.6 mm long. *Pseudopetiole* not distinct. *Leaf blades* flattened-V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight but becoming slightly curved in older and dead leaves, 9.0–25.0 cm long, 0.6–1.1 mm wide when rolled, relatively soft when fresh, moderately pungent, glabrous abaxially, densely papillose adaxially, often resinous over abaxial surface, bright green drying dull green; stomatal grooves on abaxial surface confined to central part, (2–)4 ((1–)2 either side of a moderately wide mid-rib), ±equally spaced in the central part, absent on marginal *c*. 1/3 but obscure fine ribs present; stomatal grooves on adaxial surface 10–14 (5–7 each side of mid-rib); margins sparsely minutely scaberulous with prickle hairs *c*. 0.03–0.10 mm long. *Flag-leaf* sheaths 11.5–19.3 cm long, involute, glabrous; blade 2.3–3.9 cm long. *Panicle* 12.5–20.0 cm long, 3.0–6.0 cm wide, with 12–44 spikelets total, narrowly lanceolate to lanceolate; primary axis angular to ribbed or flattened, glabrous except for minute tufts of hairs *c.* 1.0–2.0 mm long in branch axils, non-resinous; primary branches openly racemose (extreme base of longest branches never ternate). Longest primary panicle branches 2.4–5.0 cm long, with 2–5 ±uniform-sized spikelets in a loose arrangement (adjacent glumes partly overlapping), axis terete to weakly flattened and internodes between pedicels 12.0–20.0 mm long; longest *pedicels* at base of longest panicle branches (2.0–)4.0–15.0 mm long, 0.12–0.17 mm wide, becoming slightly thicker to 0.35–0.45 mm wide just below spikelet, ±filiform, terete or slightly flattened, minutely scabrous; upper lateral pedicels on branch slightly to substantially shorter than lowest ones; terminal pedicel 9.5–34.0 mm long. *Spikelet* 8.5–30.0 mm long, 3.5–10.0 mm wide (excluding awns but including glumes), the combined florets without glumes 8.5–13.0 mm long (excluding awns), loosely 5–9-flowered with 3–5 fertile florets (1–4 apparently sterile florets at apex, but these possibly immature), linear to narrowly oblong or narrowly lanceolate, terete or slightly laterally compressed at maturity; lowest rachilla internode 1.4–1.9 mm long, *c.* 0.4–0.6 mm diam., smooth or minutely scabrous, apex oblique with a marginal fringe of hairs; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* (12.5–)15.0–30.0 mm long, (2.0–)2.2–3.6 mm wide *in situ* (without flattening), narrowly lanceolate, L:W 6.2–13.0, with long-acuminate apex, distinctly longer than the combined florets (excluding awns), scarious, with narrow membranous margins, completely lacking scabrosities, prominently 7–13-nerved; mid-nerve slightly raised; lateral nerves slightly raised; margins glabrous. *Upper glume* inserted *c.* 0.3–0.6 mm above lower glume, (13.5–)15.0–30.0 mm long, similar to and subequal to lower glume, distinctly longer than the combined florets (excluding awns). *Lemma* of basal floret 15.0–34.0 mm long including awns, narrowly oblanceolate, deeply 3-lobed, 3-awned; body 5.0–6.2 mm long including callus, 1.3–1.9 mm wide, bitextured (lower part indurated, upper part chartaceous) with a sharp transition line between the two textures; indurated part with moderately dense and ±uniformly distributed appressed to lifting hairs 0.2–0.5 mm long; chartaceous part 1.0–2.1 mm long above the bitextured line, with 9 nerves in 3 groups of 3 obscure nerves radiating into the lobes; mid-lobe 10.2–26.0 mm long (including awn), very narrowly triangular at base and gradually narrowing into an awn, subequal in width to the lateral lobes; lateral lobes 14.5–16.0 mm long (including awn), narrowly triangular at base and gradually narrowing into an awn, margins lacking a membranous wing; reverse face of lemma with a transverse thickened callus of tissue across the bitexture line. *Callus of basal floret* 0.8–1.1 mm long, straight, attached obliquely, sharply pungent in face view, sharply pungent in profile, white-bearded except in midline with the longest hairs 0.2–0.5 mm long. *Upper lemmas* similar to but smaller than lowest lemma. *Palea* of basal floret distinctly shorter than lemma body, 3.2–4.0 mm long, 0.7–1.1 mm wide, obtrullate to narrowly elliptic, 2-keeled, bitextured with a ±sharp transition, lower part indurated, upper part translucent-membranous, glabrous or rarely hairy (e.g. *Craven* 7601), apex variable within same inflorescence from broadly truncate to muticous or ±acute; keels raised but not winged, margin minutely ciliate with hairs *c.* 0.2 mm long; flaps at *c.* 90° to body, *c.* 0.3–0.5 mm wide, broadest in basal part, narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules* 0.45–0.95 mm long; apex truncate, undulate, glabrous. *Anthers* 3, 2.3–4.4 mm long, exserted at maturity. *Style*s 2, *c.* 2.3–3.2 mm long. *Caryopsis* 2.0 mm long, 0.85 mm wide (only one seen). (Figures 1, 2)

Diagnostic features. Foliage resinous. Leaf sheaths glabrous on surfaces and margins. Leaves epistomatous, lacking stomatal grooves on the lateral margins of the abaxial surface. Glumes narrowly lanceolate (L:W>6), 12.5–30.0 mm long, (2.0–)2.2–3.6 mm wide. Lemmas 3-awned; callus 0.8–1.0 mm long; lemma body 1.3–1.8 mm wide, bitextured with upper membranous part appressed-hairy all over and sharply demarcated from lower indurated part by a transverse line. Palea bitextured, usually glabrous (rarely hairy). Distributed in Carnarvon and adjacent bioregions in subcoastal central Western Australia.

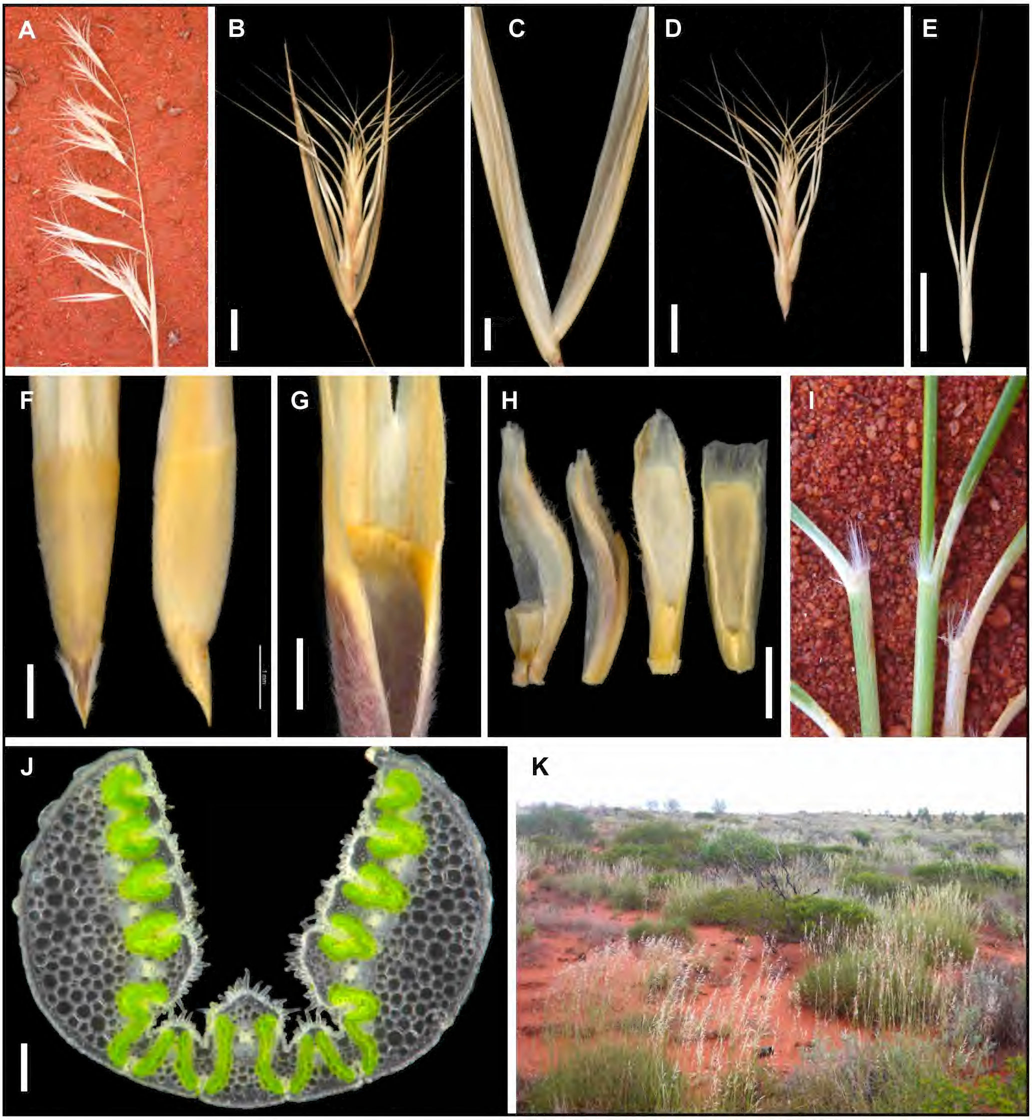

Figure 1. *Triodia avenoides*. A – inflorescence *in situ* showing typical loose form; B – spikelet, showing glumes exceeding the combined florets (excluding awns); C – close-up of glumes showing multiple nerves; D – spikelet without glumes, showing the relative position of florets; E – basal lemma showing relative awn and body lengths; F – lemma body in face and side view, showing appressed hairs on the indurated lower part and a sharp transverse line demarcating the upper membranous part; G – lemma from underside, showing the thickened callus formed at the line of change in texture (lemma bitextured); H – palea in face and side view, showing sharply differentiated texture and variation in apex; I – leaf orifice, showing resin, orifice hairs, and glabrous sheath margins; J – leaf blade in section, showing epistomatous leaf anatomy and four abaxial stomatal grooves; K – flowering plant *in situ* showing red sand plain habitat. Scale bars = 5 mm (B, D, E); 1 mm (C, E–H); 0.1 mm (J). Images from *M.D. Barrett & W. Lewandrowski* MDB 3979 (B–H), *M.D. Barrett & W. Lewandrowski* MDB 3980 (A, K), and *M.D. Barrett & B.M. Anderson* MDB 4121 (I, J). Images by M.D. Barrett; images A–C, E, F, H, J and K modified from SpiKey (Barrett *et al*. 2017), used with permission.

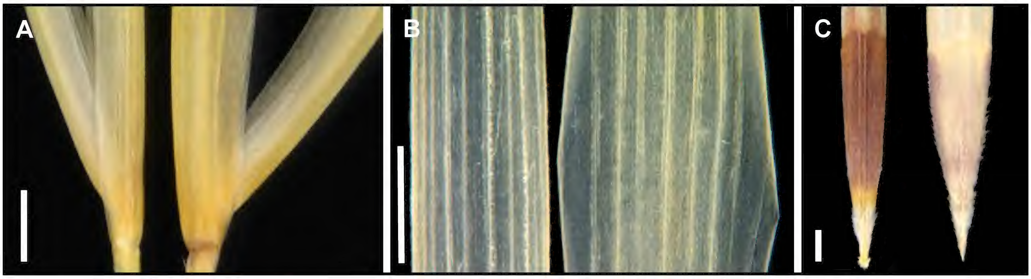

Figure 2. Comparison of critical characters distinguishing *Triodia schinzii* (left in each comparison) and *T. avenoides* (right). A – glumes in side view, showing difference in width; B – glumes boiled and flattened, showing difference in width; C – lemmas in face view without flattening, showing difference in width. Scale bars = 1 mm. Images of *T. avenoides* from *M.D. Barrett & W. Lewandrowski* MDB 3979 (A–C, right of each pair). Images of *T. schinzii* from *M.D. Barrett & W. Lewandrowski* MDB 3917 (A–C, left of each pair). Images by M.D. Barrett; images A and C modified from SpiKey (Barrett *et al.* 2017), used with permission.

Selected specimens examined. WESTERN AUSTRALIA: *c.* 50 km SW of Nanutarra, 13 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3979 (PERTH); *c.* 20 km north of Nanutarra, 13 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3980 (PERTH); Mardathuna Homestead, 24 Apr. 1995, *A.H. Burbidge* 4301 (PERTH); Site WH29, 20.7 km SW of Onslow, 9 Apr. 2009, *R. Butler & J. Fairhead* RB 021 (PERTH); SE of Five Mile Well, Cape Range, 26 May 1965, *Y. Chadwick* 2293 (PERTH); 17 km S of the Onslow South road (Koordarrie road) on the highway, 16 Sep. 1982, *L.A. Craven* 7601 (CANB, 2 sheets, MEL *n.v.*, PERTH); 34 km NE of Minilya, 11 Sep. 2004, *M.D. Crisp* 9722 (CANB, PERTH); Cane River Station, 80 km SE of Onslow, 23 May 1999, *D.J. Edinger* 1493 (PERTH); Wogoola, [Woggola] Ashburton River, 28 Aug. 1932, *C.A. Gardner* 3189 (PERTH, 4 sheets); 4 miles N of Exmouth township, 28 May 1965, *A.S. George* 6701 (PERTH); 25 km W of Learmonth, 12 July 1964, *D.W. Goodall* 1176 (PERTH); Uaroo Station, 6 July 2002, *S. van Leeuwen* 5037 (CANB, PERTH); Giralia Station, 13 Jun. 2004, *M. Maier* GIR 02-12 (DNA [DNA D0185370, as *Maier s.n.*], PERTH); 6.85 km NNW of Exmouth, 30 Sep. 2009, *R. Meissner* 2881 (PERTH); 30 km E of Nanutarra Homestead, 23 June 1976, *A.A. Mitchell* 76/122 (PERTH); 30 km N of Minilya Roadhouse, 19 Oct. 1984, *A.A. Mitchell* 1315 (PERTH); Mia Mia Station, E of Hwy between Carnarvon and Onslow, Oct. 1968, *R. O'Farrell* 6 (PERTH); Manberry Station, May 1967, *R. O'Farrell* 12 (PERTH); North West Coastal Hwy, 39 km SW of Onslow junction, 26 Mar. 1980, *B.K. Simon & J.K. Stretch* 3778 (BRI *n.v.*, NSW *n.v.*, PERTH); 13 km NE of Yannarie River along NW Coastal Hwy, 13 Feb. 1979, *A.S. Weston* 10902 (PERTH, 2 sheets).

Phenology. Fertile collections have been made between March and September, however most flowering and seeding probably occurs January–March (presence of flowering plants in January and February inferred from mature florets dehiscing in early March).

Distribution and habitat. Endemic to deep red sands and sand dunes of the Carnarvon Basin in the Carnarvon and western part of the Pilbara bioregions. It does not appear to occur on adjacent rocky ridges, gravelly soils or clay soils. A distribution map of *T. avenoides* can be found in Barrett *et al.* (2017) or Florabase (Western Australian Herbarium (1998–).

Conservation status. Not considered at risk. It is known from at least 20 locations over a 300 km range extent. Collection notes report it as 'locally dominant' (*Crisp* 9722), 'common' (*van Leeuwen* 5037) or 'not common' (*Maier* GIR 02-12), 'hundreds of plants but only on dune, not on surrounding sandplain' (*Barrett & Lewandrowski* MDB 3980), or 'many plants restricted to a small sandy area' (type, *Barrett & Anderson* MDB 4121).

Etymology. The epithet is derived from the Latin *avena* (wild oat) and *-oides* (Greek adjectival suffix indicating similarity), in reference to the similarity of the open inflorescence, especially when the glumes are empty, to members of the genus *Avena*, especially the Common Oat, *A. sativa*. This continues a long-term practice of naming *Triodia* species, which exhibit highly plastic spikelet morphology, after superficially similar genera of grasses, including *Briza*, *Bromus*, *Danthonia*, *Stipa* and *Triticum*.

Notes. *Triodia avenoides* belongs to a morphologically-defined, but probably polyphyletic (Toon *et al*. 2015), group of (epistomatous) *Triodia* species sharing awned, bitextured lemmas, including *T. acutispicula*, *T. basitricha* M.D.Barrett, *T. bitextura*, *T. caelestialis* G.Armstrong, *T. claytonii*, *T. degreyensis*, *T. schinzii* (including *T. helmsii*), and *T.* sp. Mt Ella (M.E. Trudgen 12739). *Triodia acutispicula* and *T. caelestialis* have glabrous lemma surfaces, except for 2 rows of minute hairs either side of the midline in *T. caelestialis*; all other species in the *T. bitextura* group have appressed-hairy lemma surfaces. *Triodia claytonii* has only one fertile floret per spikelet, and the lemma transverse line at the change of texture is level with the base of the lobe sinus (2-many fertile florets and transverse line at the change of texture positioned distinctly below the sinus level in other species).

Triodia basitricha, *T. bitextura s. lat.*, *T. degreyensis* and *T.* sp. Mt Ella have a blunt callus 0.25–0.7 mm long (0.8–1.7 mm long in *T. avenoides* and *T. schinzii*), and usually occur on rocky substrates (sandy substrates in *T. avenoides* and *T. schinzii*). *Triodia basitricha*, *T. bitextura s. lat.*, and *T.* sp. Mt Ella also usually have shorter glumes (which are 6.3–13.0(–15.0) mm long) while *T. avenoides* and *T. schinzii* glumes are (12.0–)14.0–30.0 mm long.

Triodia avenoides and *T. schinzii* are similar and treated by Lazarides (1997) and Lazarides *et al.* (2005) under a single species, *T. schinzii*. Both species share several characters: callus long-pungent; panicle racemose in uppermost part (2–6 nodes); indurated part of lemma appressed-pubescent, with 2 rows of slightly denser and slightly longer hairs along either side of midline (tangential light needed, sometimes obscure); margins of sheath glabrous below orifice; and substrate preference for red sand dunes and swales. *Triodia avenoides* differs from *T. schinzii* in having glumes (2.0–)2.2–3.6 mm wide (1.5–2.4 mm wide in *T. schinzii*), and lemma body 1.3–1.9 mm wide (0.80–1.25 mm wide in *T. schinzii*), all illustrated in Figure 2. The two species are allopatric. *Triodia avenoides* occurs in the Carnarvon and western Pilbara IBRA regions (Department of Environment 2013). *Triodia schinzii* is widespread in central Australia, entering the Pilbara region in the eastern half and along the northern margin (to about Point Sampson); it is also scattered in the Gascoyne bioregion to the south of the Pilbara.

The vernacular name Western Feathertop Spinifex has been suggested (Barrett *et al.* 2017), to differentiate it from true Feathertop Spinifex (*T. schinzii*).

Triodia degreyensis M.D.Barrett, *sp. nov.*

Type: De Grey Station, Pilbara region, Western Australia [precise locality withheld for conservation reasons], 22 February 2014, *M.D. Barrett & B.M. Anderson* MDB 4432 (*holo*: PERTH 08776288; *iso*: BRI, CANB, DNA).

Triodia sp. De Grey River (M.D. Barrett & B.M. Anderson MDB 4432) Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Hummock-forming *perennial*, non-resinous to weakly resinous, not obviously stoloniferous; *hummocks* compact, 30–40 cm high, 30–70 cm wide; *flowering culms* 70–100 cm high. *Vegetative culm internodes* all short (never elongated as in *T. claytonii*), 0.3–1.0 cm long, and mostly obscured by subtending foliage, red-brown, glabrous or minutely hairy at nodes; aerial roots absent or sparse. *Leaf sheaths* 1.7–4.9 cm long, 2.0–3.0 mm wide near apex, glabrous, not or weakly resinous, straw-coloured, weakly to moderately nerved; margins glabrous; margins of *orifice* truncate or oblique, with a dense fringe of ±straight or undulating hairs, the longest hairs 2.5–4.5 mm long. *Ligule* a dense fringe of hairs *c.* 0.2–0.6 mm long. *Pseudopetiole* not distinct. *Leaf blades* V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight becoming curved in older and dead leaves, 7.3–20.2 cm long, 0.6–0.8 mm wide when rolled, when fresh relatively soft, pungent, glabrous abaxially, densely papillose adaxially, non-resinous or lightly resinous over abaxial surface, bright green when fresh, drying dull green; stomatal grooves on abaxial surface confined to central part, uniformly 2 (1 either side of small mid-rib), absent on marginal *c.* 3/4 but sometimes finely obscurely ribbed; stomatal grooves on adaxial surface 10–12 (5–6 each side of mid-rib); margins minutely scaberulous with prickle hairs *c.* 0.05 mm long. *Flag-leaf* sheaths 8.5–9.0 cm long, involute, glabrous; blade not seen. *Panicle* 9.0–13.5 cm long, 1.2–3.5(–8.0) cm wide, with 12–25 spikelets total, linear to lanceolate; primary axis angular to ribbed or flattened, glabrous except minute tufts of hairs *c.* 0.3–0.9 mm long in branch axils, non-resinous; primary branches openly racemose. Longest primary panicle branches 4.0–6.5 cm long, with 2–4 ±uniform-sized spikelets in a loose arrangement (adjacent glumes not or shortly overlapping); axis terete to angular or flattened, with internodes between pedicels 12.5–18.0 mm long; longest *pedicels* at base of longest panicle branches 7.0–15.5 mm long, 0.15–0.20 mm wide, filiform, becoming slightly thicker just below spikelet, sub-terete to angular or flattened, minutely scabrous; upper lateral pedicels on branch subequal or shorter than lowest ones; terminal pedicel 18.0–27.0 mm long. *Spikelet* 9.0–17.0 mm long, 2.0–3.0 mm wide (excluding awns), 15.0–21.0 mm long, 5.0–12.0 mm wide (including awns), loosely 6–8-flowered with 4–6 fertile florets (apparently 1–3 sterile florets at apex, but these possibly immature), linear to narrowly lanceolate (excluding awns), ±terete at maturity; lowest rachilla internode 1.2–1.7 mm long, *c.* 0.15–0.20 mm diam., smooth and not scabrous, glabrous or seemingly with a tuft of hairs 0.4–0.5 mm long at the apex when the tip of the callus from the second lemma remains attached; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* 12.4–16.0 mm long, 1.8–2.5 mm wide, shorter than or subequal to the combined florets (excluding awns), narrowly lanceolate, L:W 5.4–8.9, with long-acuminate or mucronate apex, scarious, with narrow membranous margins, completely lacking scabrosities (present only as extremely minute rounded tubercles) or with minute appressed scabers *c.* 0.05 mm long only on membranous margins and apex, distinctly 7–13-nerved; mid-nerve slightly raised; lateral nerves thin and slightly raised; margins glabrous. *Upper glume* inserted 0.4–0.5 mm above lower glume, 12.4–17.0 mm long, similar to and subequal to lower glume, shorter than or subequal to the combined florets (excluding awns). *Lemma* of basal floret 13.5–19.0 mm long including awns, narrowly oblanceolate, deeply 3-lobed, 3-awned; body 3.3–4.2 mm long including callus, 1.1–1.6 mm wide *in situ*, bitextured (lower part indurated, upper part chartaceous); indurated part 2.6–3.6 mm long and almost completely covered with moderately dense and uniformly distributed appressed to lifting hairs 0.15–0.30 mm long; chartaceous part 0.5–1.0 mm long above bitextured line, glabrous, with 9 nerves in 3 groups of 3 obscure nerves radiating into lobes; mid-lobe 10.3–16.2 mm long (including awn), very narrowly triangular at base and gradually narrowing into an awn, subequal in width to the lateral lobes; lateral lobes 9.2–11.5 mm long (including awn), narrowly triangular at base and gradually narrowing into an awn, margins lacking or with only a very narrow membranous wing; reverse face of lemma with a transverse thickened callus of tissue across the bitexture line. *Callus* of basal floret 0.25–0.70 mm long, straight to curved forward, attached obliquely, acute to sharply pungent at *c.* 20–40° in face view, acute to sharply pungent in profile, white-bearded except in mid-line with the longest hairs *c.* 0.3–0.6 mm long. *Upper lemmas* similar to but smaller than lowest lemma. *Palea* of basal floret slightly longer than or subequal to the lemma body, 3.0–4.2 mm long, 0.8–1.0 mm wide, narrowly elliptic to narrowly obovate, 2-keeled, bitextured with a ±sharp transition, lower part indurated, upper part translucent-membranous, appressed-hairy over lower *c.* 3/4–5/6 of indurated part but glabrous above, apex acute to slightly erose; keels raised and thickened but not winged, margin minutely ciliate with hairs *c.* 0.2 mm long; flaps at *c.* 90° to body, *c.* 0.15–0.40 mm wide, broadest in basal part, narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules c.* 0.4 mm long, apex truncate, undulate, glabrous. *Anthers* not seen. *Style*s 2, *c.* 1.5–2.0 mm long. *Caryopsis* 2.0–2.3 mm long, 1.0–1.1 mm wide, L:W ratio 1.9–2.1:1, obovate to narrowly obovate, broadly acute to obtuse at apex, acute at base, slightly to distinctly dorsiventrally flattened in TS, pale reddish straw-coloured, base of styles not thickened; hilum 0.8–1.0 mm long, *c.* 2/5 as long as caryopsis. (Figure 3)

Diagnostic features. Foliage not or weakly resinous. Leaf sheaths glabrous on surfaces and margins. Leaves epistomatous, with uniformly one central pair of abaxial stomatal grooves and lacking stomatal grooves on the lateral margins of the abaxial surface. Glumes 12.4–17.0 mm long, 7–13 nerved, lacking scabers except near margins. Lemmas with short callus 0.25–0.70 mm long, acute to pungent but not long-pungent; lemma body bitextured with upper membranous part sharply demarcated from lower indurated part by a transverse line, the indurated part with appressed to lifting hairs; lemma lobes awned. Palea bitextured, hairy.

Other specimens examined. WESTERN AUSTRALIA [localities withheld for conservation reasons]: 11 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3962 (PERTH, K, MEL); 20 Mar. 2010, *D. Coultas* PM-16 (PERTH).

Phenology. Fertile collections have been made between February and March.

Distribution and habitat. Only known from three collections 4 km apart along a single small range (probably from a ±continuous population); the same range system extends 11 km to the north but has not been surveyed. Another poorly surveyed range system 25–40 km to the east offers additional potential habitat in the relatively featureless north-east Pilbara. A distribution map of *T. degreyensis* can be found in Barrett *et al.* (2017) or Florabase (Western Australian Herbarium (1998–).

Conservation status. *Triodia degreyensis* is listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), as *T.* sp. De Grey River (M.D. Barrett & B.M. Anderson MDB 4432). Collection notes report it as abundant with thousands of plants, but it is restricted to lower slopes of a single known range system. Active phosphate and iron ore mining leases exist on the range system. Gravel scrapes for road building have also disturbed parts of the only known population.

Etymology. The species epithet is derived from the De Grey River, in the general vicinity of the only known locality for this species.

Notes. Four other species in the Pilbara share the combination of epistomatous leaves, narrowly-lanceolate glumes, awned lemma lobes and bitextured lemmas with a transverse line at maturity: *Triodia avenoides*, *T. basitricha*, *T. schinzii* and *T.* sp. Mt Ella (M.E. Trudgen 12739). *Triodia basitricha* has shorter glumes 10.0–12.5 mm long (12.4–16.0 mm long in *T. degreyensis*) and hairs on the leaf sheath surfaces (glabrous in *T. degreyensis*). *Triodia degreyensis* differs from all of these by consistently having only two abaxial stomatal grooves (usually four in the other species).

Triodia avenoides and *T. schinzii* are larger plants with inflorescences 100–170 cm tall (70–100 cm tall in *T. degreyensis*), and have a long-pungent callus 0.8–1.5 mm long (broadly acute to shortly pungent and 0.25–0.70 mm long in *T. degreyensis*), glumes usually longer than the spikelet excluding awns (glumes shorter than to subequal to the spikelet in *T. degreyensis*), glabrous or rarely hairy palea

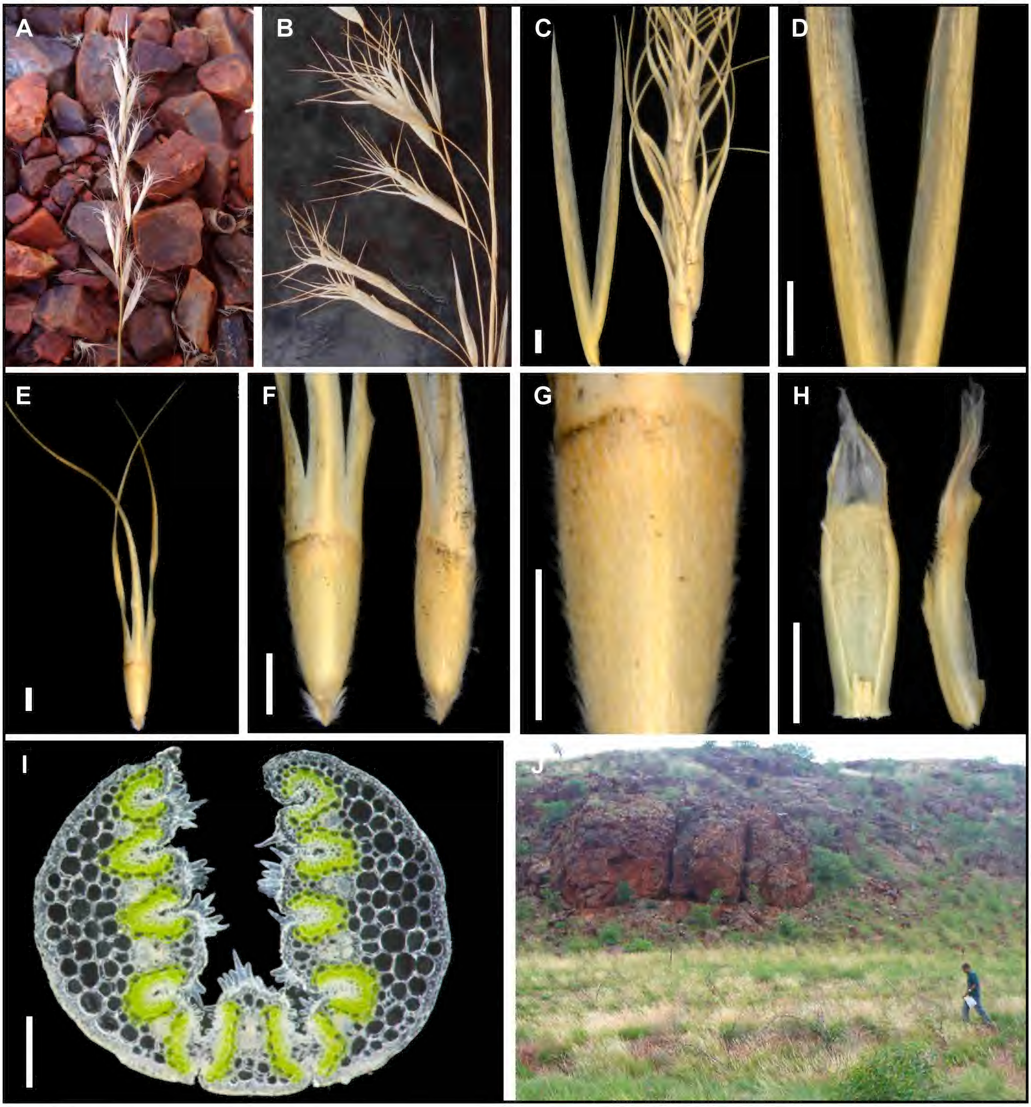

Figure 3. *Triodia degreyensis*. A – inflorescence *in situ* showing typical form; B – basal branches of inflorescence showing elongated pedicels; C – spikelet with glumes separated, showing glumes subequal to the combined florets; D – close-up of glumes showing multiple nerves, a key difference to *T. bitextura s. lat.* which usually has 3–5 nerves; E – basal lemma showing relative awn and body lengths; F – lemma body in face and side view, showing appressed hairs on the indurated lower part, and a sharp transverse line demarcating the upper membranous part (lemma bitextured); also note the callus which is shorter and more broadly acute than in *T. avenoides* and *T. schinzii* (cf. Figs. 1, 2, 5); G – close up of lemma body in face view, detailing the indumentum of appressed hairs; H – palea in face and side view, showing sharply differentiated (bitextured) texture, and indumentum; I – leaf blade in section, showing epistomatous leaf anatomy and two abaxial stomatal grooves; J – flowering plants *in situ* (straw coloured inflorescences in the mid-ground) showing habitat on gravel at foot of rocky slope (gravel substrate visible in background of A). Scale bars = 1 mm (C–H); 0.1 mm (I). Images from *M.D. Barrett & W. Lewandrowski* MDB 3962 (B–H), and *M.D. Barrett & B.M. Anderson* MDB 4432 (A, I, J). Images by M.D. Barrett; images C, F, G and I modified from SpiKey (Barrett *et al.* 2017), used with permission.

(palea hairy in *T. degreyensis*) and grow on sand flats and dunes (*T. degreyensis* grows on rocky or gravelly slopes).

Triodia sp. Mt Ella (M.E. Trudgen 12739) has shorter glumes up to 7.5–12.0 mm long (12.4–16.0 mm long in *T. degreyensis*) and is copiously resinous (not or weakly resinous in *T. degreyensis*).

Outside of the Pilbara region, four other species with awned, bitextured lemmas have been described: *T. acutispicula*, *T. bitextura*, *T. caelestialis* and *T. claytonii*. *Triodia acutispicula* and *T. caelestialis* have lemmas glabrous or with only 2 rows of minute hairs along the midline (hairy all over the lower surface in *T. degreyensis*). *Triodia claytonii* has only 1 fertile floret per spikelet and glumes 4.6–8.5 mm long (4–6 fertile florets and glumes 12.4–17.0 mm long in *T. degreyensis*). *Triodia bitextura* is a very variable species, but shares the short callus (0.25–0.70 mm long in *T. bitextura*) and abundant appressed lemma body hairs with *T. degreyensis*. *Triodia bitextura* is an extremely widespread and variable species as currently treated (Barrett & Trudgen 2018) that is polyphyletic in both nuclear ribosomal and chloroplast phylogenies (e.g. Toon *et al.* 2015, Supplementary data 3.1–3.4), and will require detailed investigation to stabilise its circumscription. Although most characters of *T. bitextura s. lat.* overlap those of *T. degreyensis* when taken as a whole, various forms of *T. bitextura* can be distinguished by having at least one, and usually two or more, of the following characters: glumes 3–5-nerved or 5–sub-7-nerved with at least 2 nerves indistinct (7–13-nerved in *T. degreyensis*, at least 7 nerves strong), glumes <12.5 mm long (12.4–17.0 mm in *T. degreyensis*), glumes scabrous all over surface (lacking scabers or scabrous only near margin in *T. degreyensis*), leaf sheaths ciliate (glabrous in *T. degreyensis*), or foliage copiously resinous (not or only weakly resinous in *T. degreyensis*).

DNA sequences (ITS and ETS regions; M.D. Barrett, unpublished data) indicate that the closest relative of *T. degreyensis* is *T. avenoides*, which occurs on sand in the west Pilbara.

The vernacular name De Grey Spinifex has been suggested (Barrett *et al.* 2017).

Triodia karijini M.D.Barrett & S.J.Dillon, *sp. nov*.

Type: Hamersley Range, Western Australia [precise locality withheld for conservation reasons], 26 February 2014, *M.D. Barrett & B.M. Anderson* MDB 4475 (*holo*: PERTH 08776253; *iso*: BRI, CANB, DNA, K, NSW).

Triodia sp. Karijini (S. van Leeuwen 4111), Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Perennial, not resinous to weakly resinous, not obviously stoloniferous; *hummocks* with a tussock form, dense, compact, 20–60 cm high, 20–70 cm wide; *flowering culms* 35–120 cm high. *Vegetative culm internodes* all short (never elongated as in *T. claytonii*), 1.0–3.0 mm long, obscured by subtending foliage, red-brown, shiny, glabrous; aerial roots absent. *Leaf sheaths* 4.7–11.3 cm long, 3.5–4.4 mm wide near apex, surface glabrous or sparsely to moderately densely pilose with hairs 3.0–4.5 mm long and most dense over central areas, not resinous, straw-coloured, distinctly nerved in central 2/3 or nearly to margin; margins glabrous or pilose with hairs 0.5–3.0 mm long; margins of *orifice* oblique to truncate, with a dense fringe of hairs, the longest hairs 0.6–4.5 mm long. *Ligule* a dense fringe of hairs *c.* 0.3–1.0 mm long. *Pseudopetiole* not distinct. *Leaf blades* V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight but becoming curved in older and dead leaves, 19.0–33.5 cm long, 0.3–0.7 mm wide when rolled, when fresh relatively soft, weakly pungent, non-resinous or with slight traces of resin limited to the line of resin-producing cells on lateral faces of the blade, glabrous abaxially, densely papillose adaxially, mid-green, drying dull green; stomatal grooves on abaxial surface confined to central part, (2–)4 ((1–)2 either side of moderately broad mid-rib), unequally spaced, absent on marginal *c.* 1/3 but sometimes very finely streaked; stomatal grooves on adaxial surface 10–16 (5–8 each side of mid-rib); margins smooth (scabrosities absent or extremely minute and ±indistinguishable from papillae). *Flag-leaf* sheaths 9.8–15.0 cm long, involute, glabrous; blade 2.7–3.4 cm long. *Panicle* 12.5–20.5 cm long, 1.0–3.0 cm wide, with 48–93 spikelets total, moderately dense to loose, linear to narrowly lanceolate, glabrous or very rarely with a few minute hairs *c.* 0.5 mm long in branch axils, non-resinous; primary axis angular to ribbed; primary branches openly racemose or longest branches also sparsely branched (ternate). Longest primary panicle branches 1.5–4.4 cm long, with 3–6 uniform-sized spikelets in a loose arrangement (adjacent glumes partly overlapping); axis sub-terete to angular, internodes between pedicels 3.0–8.0 mm long; longest *pedicels* at base of longest panicle branches 2.5–11.0 mm long, 0.1–0.2 mm wide, becoming slightly thicker just below spikelet, sub-terete to angular, minutely scabrous; terminal pedicel 4.7–10.0 mm long. *Spikelet* 5.5–9.5 mm long, 1.0–4.1 mm wide (including lobes), loosely 5–6-flowered with 4–5 fertile florets (apparently 0–2 sterile florets at apex, but these possibly immature), narrowly lanceolate to narrowly elliptic, not or weakly compressed at maturity; lowest rachilla internode 0.5–1.0 mm long, *c.* 0.15 mm diam., smooth, glabrous; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* 3.0–6.3 mm long, 0.7–1.2 mm wide, narrowly lanceolate, L:W (3.0–)5.1–7.8, apex narrowly acute, shorter than the combined florets, scarious, lacking membranous margins, with minute scabrosities less than 0.08 mm long over whole surface, 3–5-nerved; mid-nerve very narrow and slightly raised; lateral nerves narrow and scarcely raised; margins glabrous or sparsely ciliate (cilia to 0.2 mm long). *Upper glume* inserted *c.* 0.2–1.5 mm above lower glume, 3.4–6.3 mm long, similar to and subequal or slightly longer than lower glume, shorter than the combined florets. *Lemma* of basal floret 5.7–7.1 mm long including lobes, lanceolate, deeply 3-lobed with mid-lobe longer and drawn out into a short awnlet (which could be interpreted as either a long lobe or a short awn); body 3.7–4.2 mm long including callus, not bitextured, chartaceous throughout except for a very narrow membranous margin the lower 1/3–5/6 of body with dense appressed to ascending hairs 0.1–0.4 mm long confined to *c.* 11 longitudinal rows, the upper part with 9 nerves in 3 groups of 3 obscure nerves radiating into lobes; mid-lobe 2.0–3.0 mm long (including ‘awn’ if interpreted as such), narrowly triangular at base, narrowing into a short awnlet, subequal in width or slightly narrower than lateral lobes; lateral lobes 0.9–1.7 mm long, narrowly triangular at base lacking an awnlet or with a very short awnlet, margins lacking a membranous wing. *Callus* of basal floret 0.2–0.4 mm long, slightly curved, attached obliquely, acute but abruptly blunt at tip in face view, acute in side view, white-bearded in two lines either side in midline with the longest hairs 0.1–0.4 mm long. *Upper lemmas* similar to but smaller than lowest lemma, but lobes becoming progressively more awn-like as lemma body decreases in size. *Palea* of basal floret slightly longer than lemma body, 3.4–4.5 mm long, 0.5–0.8 mm wide, oblanceolate to narrowly oblanceolate, 2-keeled, uniformly textured, ±chartaceous, glabrous, apex acute to erose; keels raised but not winged or with a minute wing *c.* 0.05 mm wide, margin scabrous with scabrosities up to 0.15 mm long; flaps *c.* 0.10–0.25 mm wide, broadest just below middle, narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules* 0.6–0.8 mm long, falcate to broadly obovate, at apex ±truncate to obliquely 2-lobed, entire to undulate, glabrous or sparsely ciliate. *Anthers* 3, 2.2–2.5 mm long, exserted at maturity (field observations on type specimen). *Style*s 2, *c.* 1.4 mm long. *Caryopsis* not seen. (Figure 4)

Diagnostic features. Hummocks with dense tussock form habit. Leaf sheaths glabrous or sparsely to moderately densely pilose on surfaces and/or margins, the hairs up to 4.5 mm long. Ligule 0.3–1.0 mm long. Leaf blades epistomatous, not or weakly resinous. Inflorescence 12.5–20.5 cm long. Glumes narrowly lanceolate, L:W (3.0–)5.1–7.8. Lemmas not bitextured, 3-lobed, not awned or with a short awnlet, the mid lobe 2.0–3.0 mm long. Habit on outcropping banded iron ridges above 900 m altitude.

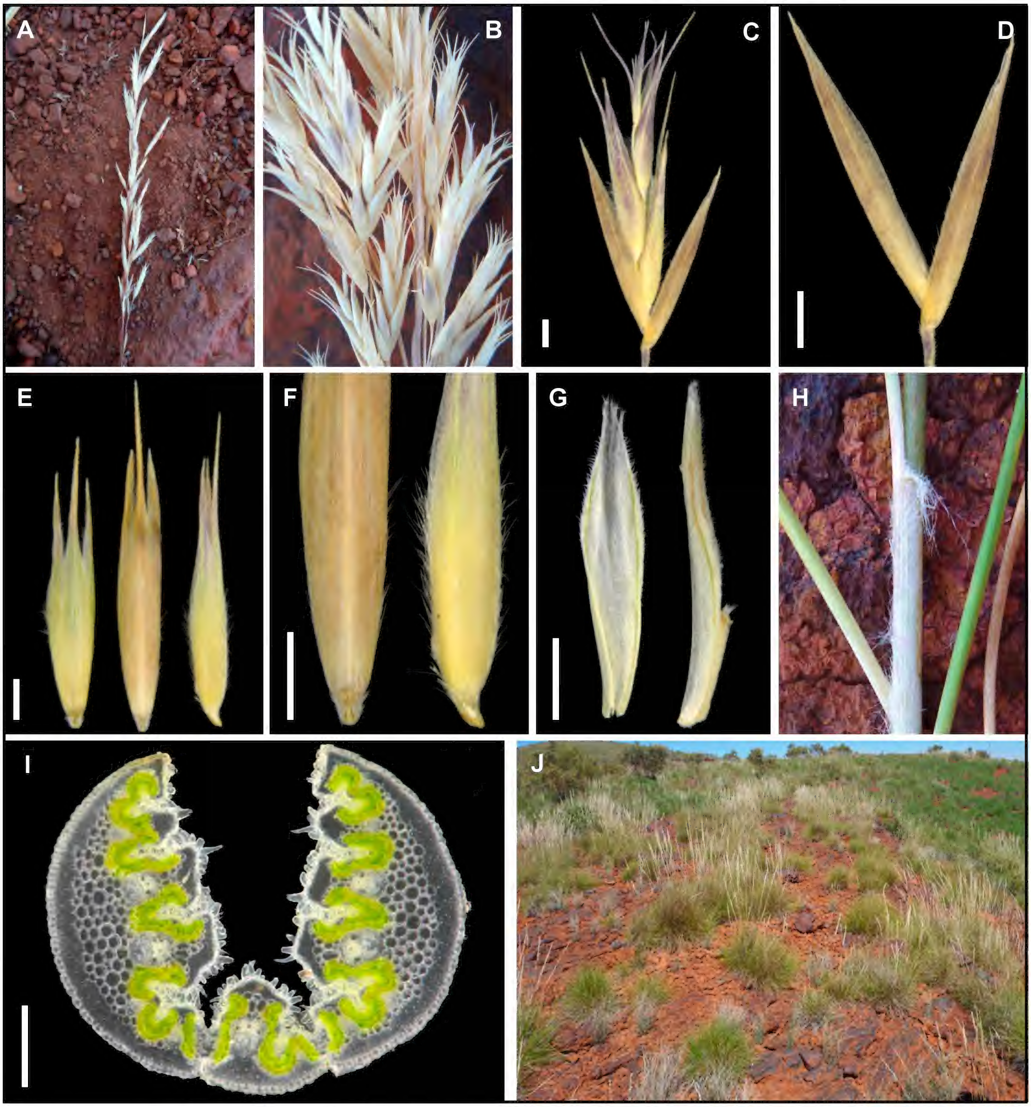

Figure 4. *Triodia karijini*. A – inflorescence showing typical form; B – close up of inflorescence showing spikelet variation; C – spikelet, showing glumes shorter than the combined florets, and lemma awnlets; D – glumes showing narrowly lanceolate shape; E – basal lemmas in face and side view showing variation in relative lobe/awnlet and body lengths; F – close up of lemma body in face and side view, showing appressed hairs arranged in longitudinal rows and uniform texture; G – palea in face and side view, showing uniform texture and lack of indumentum; H – leaf sheath and orifice, showing lack of resin (in this plant; lightly resinous in others), orifice hairs, and hairy sheath surfaces and margins; I – leaf blade in section, showing epistomatous leaf anatomy and two abaxial stomatal grooves; J – flowering plants *in situ* showing habit on ridge of BIF on a mountain plateau (greener plants visible in the top right are *T. pungens*, on non-BIF substrate). Scale bars = 1 mm (C–G); 0.1 mm (I). Images from *M.D. Barrett & B.M. Anderson* MDB 4475. Images by M.D. Barrett; images B–J modified from SpiKey (Barrett *et al*. 2017), used with permission.

Other specimens examined. WESTERN AUSTRALIA [localities withheld for conservation reasons]: 18 May 2010, *J. Bull* ONS SFC 109.01 (PERTH, 2 sheets); 23 Sept 2010, *J. Bull* ONS SFD 194.03 (PERTH); 30 July 1998, *S. van Leeuwen* 3502 (CANB – currently as *T. melvillei*, PERTH); 18 Aug. 1998, *S. van Leeuwen* 3817 (AD *n.v.* – currently as *T. melvillei*, CANB – currently as *T. melvillei*, PERTH); 29 Sep. 1998, *S. van Leeuwen* 4111 (PERTH, CANB – currently as *T. brizoides*).

Phenology. Fertile collections have been made between February and May.

Distribution and habitat. *Triodia karijini* occurs in the central Hamersley Range. Its distribution is centred on Karijini National Park, and also on mountains adjacent to the north and east of the Park. A distribution map of *T. karijini* can be found in Barrett *et al.* (2017) or Florabase (Western Australian Herbarium (1998–).

Conservation status. *Triodia karijini* is listed as Priority Two under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), under the name *T.* sp. Karijini (S. van Leeuwen 4111). It is known from just four locations over a 100 km distance in the Hamersley Range, all over 900 m altitude. Collection notes report it as 'common' (*S. van Leeuwen* 3502, 3817, 4111), '9%' [of a 50 × 50 quadrat] (*J. Bull* ONS SFC 109.01), or 'scattered plants' (*J. Bull* ONS SFD 194.03). An estimated 400 plants were found restricted to a single BIF outcrop at the type locality (*Barrett & Anderson* MDB 4475), however other populations are known elsewhere on the same mountain.

Etymology. The epithet is from *Karijini* meaning 'hilly place' in the Banyjima language, in reference to both the habitat on hills and the nearby Karijini National Park, and is used here as a noun in apposition.

Notes. The sub-awned lemma lobes of *T. karijini* provide yet another example of an intermediate between the old concepts of *Plectrachne* and *Triodia*, delimited by the presence or absence of awns. As noted by Lazarides (1995), this character state is untenable as a generic character, and the presence of an awn is homoplastic across *Triodia s. lat.* (Toon *et al.* 2015).

Triodia karijini was included in the phylogenetic trees of Toon *et al*. (2015) under the name *T. melvillei* (voucher *S. van Leeuwen* 3817), divergent from *T. melvillei s. str.* (represented by the specimen *M.D. Crisp* 9731, which was in turn labelled *T. bynoei* in Toon *et al*. (2015)).

Since lemma lobes of *T. karijini* are not obviously awned, *T. karijini* might be compared to taxa around *T. pungens* R.Br.; however, glumes and lemma lobes are more elongate than in *T. pungens* and allies, reminiscent of awned *Triodia* species, so workers familiar with *T. melvillei* and *T. pisoliticola* might look for it there (where its phylogenetic affinities lie).

Morphologically, *T. karijini* is most similar to *T. veniciae* (Barrett 2019); both species share narrow lemma lobes 2.0–3.2(4.5) mm long that could be interpreted as awnlets. *Triodia karijini* has non-resinous to weakly resinous foliage (copiously resinous in *T. veniciae*); palea always glabrous (usually some hairs present in *T. veniciae*); and 3–6 spikelets on longest primary panicle branches (7–14 in *T. veniciae*). *Triodia karijini* is only known from above 900 m on ironstone ridges on mountains in the Hamersley Range, south of the Fortescue River valley, while *T. veniciae* is only known from shale slopes in the Chichester range north of the Fortescue River valley, at 450–520 m altitude.

Triodia karijini is also similar to *T. lutiteana*, but differs in more compact, tussocky clumps to 30–60 cm high and inflorescences 35–120 cm high (more tangled hummocks 60–80 cm high and inflorescences to 160 cm high in *T. lutiteana*); not or weakly resinous foliage (copiously resinous in *T. lutiteana*); longer lemma lobes 2.0–3.0 mm long (0.3–2.1 mm long in *T. lutiteana*); glabrous sheath margins or with hairs to 3.0 mm long scattered over the surface (densely woolly with hairs 3–5 mm long on sub-margins in *T. lutiteana*); ligule hairs 0.3–1.0 mm long (1.5–4.0 mm long in *T. lutiteana*); leaf blades 0.3–0.7 mm wide in rolled leaves (0.9–1.3 mm wide in *T. lutiteana*); shorter inflorescences 12.5–20.0 mm long with fewer (48–93) total spikelets (30.0–37.5 mm long with 112–259 spikelets in

T. lutiteana); and habitat on banded iron ridges above 900 m altitude (*T. lutiteana* is restricted to shale, 430–600 m altitude). The two species are allopatric along the Hamersley Range, with *T. lutiteana* restricted to the west of the constriction in the Hamersley Range where the Nanutarra-Munjina Road passes near Hamersley Gorge, while *T. karijini* only occurs to the east.

Although superficially similar to *T. melvillei*, which grows in the vicinity, *T. karijini* differs in having dense compact tussocks (larger, more open hummocks in *T. melvillei*), being non-resinous to weakly resinous (conspicuously resinous in *T. melvillei*), and having lemma lobes 2.0–3.0 mm long and not awned (lobes 5–14 long and prominently awned in *T. melvillei*). In the Hamersley Range their habitats are usually discrete, with *T. karijini* restricted to outcropping banded iron ridges above 900 m and *T. melvillei* usually on loam or gravelly plains; however, an anomalous cluster of *T. melvillei* was found on a banded iron ridge about 1 km from the type locality of *T. karijini*. South and east of the Pilbara, *T. melvillei* is usually found on rocky substrates, so the Pilbara habitat preference seems to be a local phenomenon.

Phylogenetically, ITS and ETS phylogenies (M.D. Barrett, unpublished data) place *T. karijini* remote from *T. melvillei*, in a group with *T. lutiteana* and *T. pisoliticola*. *Triodia karijini* differs from *T. pisoliticola* by its shorter lemma lobes 2–3 mm long in lowest lemma and lacking awns (lemma lobes in lowest lemma 4.2–9.0 mm long with a distinct awn in *T. pisoliticola*), erect and shorter leaves 19.0–33.5 cm long (leaves becoming lax and curved at maturity and 24–59 cm long in *T. pisoliticola*), and having a distribution in the central Hamersley Range, while *T. pisoliticola* is disjunct in the Millstream-Pannawonica area in the west Pilbara. Anatomically, the abaxial band of sclerenchyma below the abaxial epidermis is unusually thick in both *T. karijini* and *T. pisoliticola* (compare images of leaf sections in Barrett *et al*. (2017) and Fig. 4I here).

Triodia karijini differs from *T. pungens* and *T. epactia* by having non-resinous to weakly resinous foliage (versus strongly resinous in the other two species); forming denser, more compact hummocks; and having narrower glumes, lemmas and lemma lobes.

Some plants in the type population were observed with partially burnt bases, indicating that the species is able to resprout after fire.

Co-occurring species. Co-occurring species are the Pilbara form of *T. pungens*, and the amphistomatous species *T. wiseana* C.A.Gardner. At the type locality of *T. karijini*, a single plant of the larger, resinous species *T. melvillei* was found on the same mountain (about 1 km away), an aberrant habitat since the species is nearly always found on plains in the Pilbara (but often on rocky hills south and east of the Pilbara). *Triodia* sp. Mt Ella also occurs nearby at the type locality, but is highly resinous and has bitextured, awned lemmas.

The vernacular name Pilbara Mountain Spinifex has been suggested (Barrett *et al.* 2017).

Triodia lutiteana M.D.Barrett & P.-L.de Kock, *sp. nov.*

Type: Near Silvergrass Mine, Western Australia [precise locality withheld for conservation reasons], 5 March 2018, *P.-L. de Kock* PLDK 1107 (*holo*: PERTH 09180141; *iso*: BRI, CANB, DNA, K, MEL, NSW).

Triodia sp. Silvergrass (P.-L. de Kock BES 00808) Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Hummocks with tussock form, *perennial*, copiously resinous and highly aromatic, not obviously stoloniferous; *hummocks* densely compact, 60–80 cm high, 60–80 cm wide; *flowering culms* 150–160 cm high. *Vegetative culm internodes* all short (never elongated as in *T. claytonii*), 4.0–24.0 mm long, and obscured by subtending foliage, dark red-brown, sparsely to moderately pilose becoming glabrous; aerial roots absent. *Leaf sheaths* very narrowly triangular, 10.0–16.0 cm long, 2.5–6.5 mm wide near apex, 4.0–9.0 mm wide near base, strongly aromatic-resinous at least near apex, straw-coloured, moderately strongly nerved, glabrous on surface except sparsely to densely hirsute with straight to tangled hairs 3.0–5.0 mm long in a sub-marginal zone 0.5–1.5 mm wide, the hairs with a visible lumen; lateral sheath margins densely hirsute with straight to crisped somewhat thickened hairs 3.5–9.0 mm long, on lower sheath margins close to nodes these tangled with the sub-marginal hairs into a thick, dense woolly band; margins of *orifice* ±truncate to shortly auriculate, with a dense fringe of straight to crisped hairs, the longest hairs 3.2–8.0 mm long. *Ligule* a dense, thick band of hairs 1.5–4.0 mm long, usually partly embedded in resin. *Pseudopetiole* not distinct. *Leaf blades* V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight but becoming curved or sinuate in older and dead leaves, 21.0–42.0 cm long, 0.9–1.3 mm high when rolled, 0.8–1.2 mm wide when rolled, *c.* 2.0 mm wide in unrolled leaves, when fresh relatively soft, moderately pungent, glabrous abaxially, densely papillose adaxially, resinous over abaxial surface, mid- to dark green when fresh, drying pale green; stomatal grooves on abaxial surface confined to central part, 4 (2 either side of a scarcely raised mid-rib), absent on marginal *c.* 2/5 but sometimes finely obscurely ribbed; stomatal grooves on adaxial surface 10–12 (5–6 each side of mid-rib); margins minutely scaberulous with prickle hairs *c.* 0.05–0.10 mm long. *Flag-leaf* sheaths 14.0–23.0 cm long, involute, densely ciliate with hairs 2.5–4.0 mm long on exposed margin; blade 4.0–34.0 cm long. *Panicle* 30.0–37.3 cm long, (3.0–)6.0–28.0 cm wide, with 112–259 spikelets total, lanceolate to ovate, moderately dense to loose; primary axis angular and ribbed or flattened, glabrous except for minute tufts of hairs *c.* 1.5–3.0 mm long in branch axils, non-resinous; primary branches openly racemose except for base of branches in the lower half prominently ternate. Longest primary panicle branches 9.5–20.0 cm long, terete to angular or weakly flattened, with 9–19 loosely arranged, ±uniform-sized spikelets in a loose arrangement (adjacent glumes not or slightly overlapping); axis terete to angular or prominently flattened, with internodes between pedicels 13.0–16.5 mm long; longest *pedicels* at base of longest panicle branches 0.7–6.0 mm long, 0.2–0.3 mm wide, filiform to slender, becoming slightly thicker just below spikelet, minutely antrorsely scabrous; upper lateral pedicels on branch often gradually becoming shorter than lowest ones, down to 1.0 mm long; terminal pedicel 4.0–14.5 mm long. *Spikelet* 6.0–13.0 mm long, 1.2–2.0 mm wide, loosely 3–7-flowered with 3–6 fertile florets (apparently 0–2 sterile florets at apex, but these possibly immature), narrowly lanceolate, sub-terete to slightly laterally compressed at maturity; lowest rachilla internode 0.9–1.5 mm long, *c.* 0.2 mm diam., slightly laterally compressed in section, not ribbed, minutely scabrous or smooth, glabrous; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* 4.5–8.0 mm long, 1.1–2.1 mm wide, narrowly lanceolate to lanceolate, L:W 3.2–6.4, apex muticous, acute or acuminate and usually shortly mucronate with mucro 0.2 mm long, 0.5–0.9 as long as the combined florets (including lobes), scarious, chartaceous, margins undifferentiated and not membranous, with minute scabrosities over whole surface, 3–5-nerved; mid-nerve raised into a narrow thickened keel; lateral nerves scarcely to moderately raised; margins glabrous. *Upper glume* inserted *c.* 0.3–0.5 mm above lower glume, 4.4–7.8 mm long, 1.6–2.1 mm wide, similar to and subequal to lower glume, much shorter than the combined florets (excluding awns). *Lemma of basal floret* 4.8–7.2 mm long including lobes, narrowly lanceolate to narrowly oblong, shortly to deeply 3-lobed; body 4.5–5.6 mm long including callus, 1.0–1.5 mm wide without flattening, uniformly chartaceous to somewhat indurated, not bitextured, with scattered sparse to moderately dense appressed to ascending hairs 0.3–0.7 mm long somewhat obscurely arranged in lines between the nerves all over the lower 2/3–3/4 of body, 9 nerves in 3 groups of 3 obscure nerves radiating into base of lobes; mid-lobe 0.2–2.1 mm long (on most specimens less than 1 mm long), triangular to narrowly triangular, acute, not awned but sometimes shortly acuminate, subequal or slightly longer and slightly to distinctly narrower than lateral lobes; lateral lobes 0.3–0.8 mm long, triangular, acute, not awned, margins with lacking a membranous wing. *Callus* of basal floret 0.2–0.5 mm long, straight to slightly curved, attached obliquely, broadly to sharply acute in face view, sharply acute in profile, white-bearded either side of a broad glabrous midline with the longest hairs *c.* 0.4–0.6 mm long. *Upper lemmas* similar to but smaller than lowest lemma. *Palea* of basal floret subequal to or slightly longer than lemma body (shorter than body in rare specimens with stunted or immature paleas), 4.5–5.7 mm long, 0.80–0.95 mm wide, lanceolate to oblanceolate, 2-keeled, not bitextured, membranous-chartaceous, sparsely to moderately densely ascending-hairy in basal 1/3–2/3, glabrous in apical part, apex acute to broadly acute or notched; keels raised but not winged or with a narrow membranous wing to 0.1 mm wide, margin densely minutely ciliate for most of length with cilia up to *c.* 0.05-0.10 mm long; flaps *c.* 0.1–0.2 mm wide, broadest in central part, much narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules* 0.5–0.9 mm long, apex broadly and obliquely rounded-truncate, ±entire, glabrous. *Anthers* 3, 2.5–2.8 mm long, exserted at maturity. *Style*s 2, *c.* 1.5–2.0 mm long. *Caryopsis* not seen. (Figure 5)

Diagnostic characters. Sheaths densely resinous, margins densely hirsute, submargins sparsely to moderately hirsute; ligule hairs 1.5–4.0 mm long. Glume 4.4–8.0 mm long, narrowly lanceolate to lanceolate, L:W 3.2–6.4. Lowest lemma 4.8–7.2 mm long including lobes, shortly to deeply 3-lobed, not bitextured, with scattered sparse to moderately dense appressed to ascending hairs 0.3–0.7 mm long somewhat obscurely arranged in lines, not awned, the mid-lobe 0.2–2.1 mm long (on most specimens less than 1 mm long), lateral lobes 0.3–0.8 mm long. Restricted to shale or mudstone substrate.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 13 Oct. 2018, *S. Colwill* BES 00956 (PERTH); 22 Sep. 2017, *C. Flaherty* BES 00948 (PERTH); 27 May 2018, *M. Hay* 1803_04-02 (PERTH); 25 May 2018, *M. Hay & M. Macdonald* 1803_R9-01 (PERTH); 5 Mar. 2018, *P.-L. de Kock* PLDK 1108 (CANB, PERTH); 5 Mar. 2018, *P.-L. de Kock* PLDK 1109 (AD; PERTH); 16 Sep. 2017, *P.-L. de Kock* BES 00808 (PERTH); 27 June 2017, *P.-L. de Kock* BES 00952 (PERTH); 10 Oct. 2018, *P.-L. de Kock* BES 00953 (PERTH); 21 Sep. 2017, *P.-L. de Kock* BES 00954 (PERTH); 25 Apr. 2017, *P.-L. de Kock* BES 00957 (PERTH); 16 Sep. 2017, *P.-L. de Kock & M. Greenham* BES 00949 (PERTH); 16 Sep. 2017, *P.-L. de Kock & M. Greenham* BES 00950 (PERTH); 10 Oct. 2018, *M. Maier* BES 00947 (PERTH); 21 Sep. 2017, *B. Morgan & S. Colwill* BES 00955 (PERTH); 30 June 2017, *B. Morgan & B. Eckermann* BES 00951 (PERTH).

Phenology. Fertile collections have been made in March.

Distribution and habitat. Occurs exclusively on shale hills and slopes of the Nammuldi-Silvergrass area with a known range of 75 km from north-east of Nammuldi Airport to south-west of east Mt Farquhar in the western Hamersley Range, Pilbara Region, Western Australia. In this highly restricted habitat it is typically the dominant species, growing in near monocultures. Total census of known populations was 31,330 plants in 2019.

Conservation status. *Triodia lutiteana* is listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), under the name *T.* sp. Silvergrass (P.-L. de Kock BES 00808). It is known from six discrete areas over about 75 km distance. Collection notes report it as '15% cover', '25% cover' [of 50 × 50 m quadrats] or 'locally abundant' (*M. Hay* 1803_04-02, *M. Hay & M. Macdonald* 1803_R9-01, *P.L. de Kock* PLDK 1109, respectively).

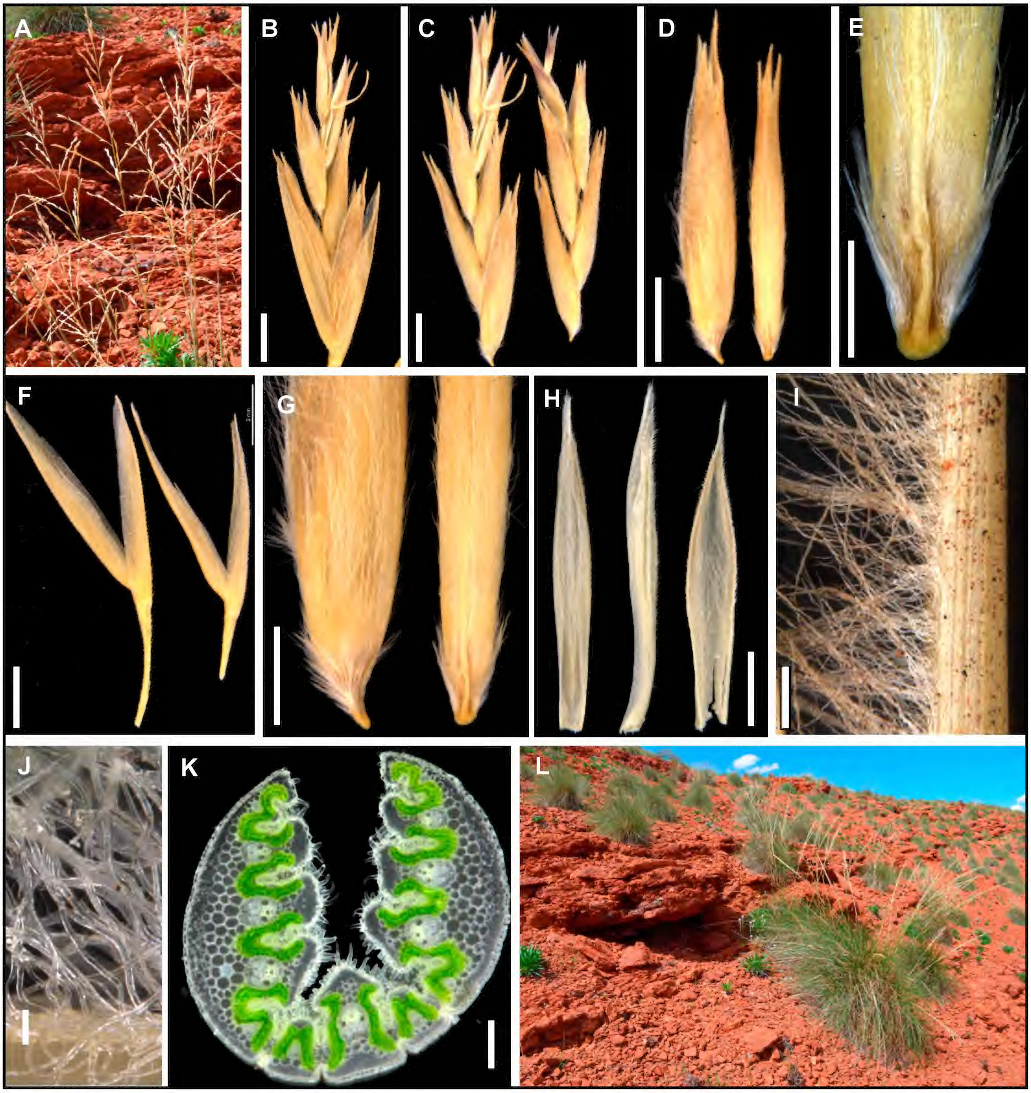

Figure 5. *Triodia lutiteana.* A – inflorescences *in situ* showing typical form; B – spikelet, showing glumes shorter than the combined florets; C – spikelets without glumes showing variation in florets and lemma lobes; D – basal lemmas in side and face view showing indumentum and lemma lobes; E – close up of basal lemma body showing hairs somewhat arranged in lines; F – glumes, showing shape and variation; G – close up of lemma body in side and face view, detailing the indumentum of appressed to ascending hairs, and difficulty observing the tendency of hairs to occur in lines when the indumentum is denser (*cf.* image E); H – palea in face and side view, showing uniform texture and indumentum; I – leaf sheath surface, showing diagnostic glabrous and resinous face, with densely hirsute sheath margins and sub-margins; J – leaf sheath marginal hairs magnified, showing undulate, tangled form, and hollow lumen; K – leaf blade in section, showing epistomatous leaf anatomy and two abaxial stomatal grooves; J – flowering plants *in situ*, showing typical sparse occurrence in near monocultures, restricted to specific shale / mudstone substrate. Scale bars = 1 mm (B–I); 0.5 mm (E); 0.1 mm (J); 0.2 mm (K). Images from *P.L- de Kock* 1109. Images by M.D. Barrett (B–K) and P.-L. de Kock (A, L).

Etymology. The epithet is from *lutite*, an old geological term referring to any type of mudstone (including shale), which in turn is derived from Latin *lutum*, mud, and the suffix *-ana*, indicating a connection, all in reference to the very tight association of this species with shale geology.

Notes. *Triodia lutiteana* was unknown before April 2017, when it was discovered by P.-L. de Kock, then at Biota Environmental Sciences, conducting a survey for Fortescue Metals Group Ltd.

Triodia lutiteana, along with *T. karijini* and *T. veniciae*, is one of three Pilbara species that share the combination of epistomatous leaf anatomy, narrowly lanceolate glumes [L:W>(3.2–)4.0] with central lobe of lowest lemma 0.3–3.2 mm long, and lemma lobes not awned or with at most a short awnlet. The only other species of *Triodia* with these characteristics is *T. hubbardii* N.T.Burb. from central Australia. *Triodia triaristata* Lazarides from central Australia is also similar but has a longer lemma mid-lobe (2–)3.5–5 mm long (Lazarides *et al*. 2005).

Differences between *Triodia lutiteana* and *T. karijini* are given under the latter species.

Triodia lutiteana shares the robust resinous hummocks and the same shale habitat of *T. veniciae*, but differs in having dense woolly hairs 3–5 mm long restricted to a submarginal zone (leaf sheath margin glabrous in *T. veniciae*, although sheath *surface* can have scattered hairs 1.5–3.2 mm long all over; see Figure 7B); longer ligule hairs 1.5–4.0 mm long (0.5–0.9 mm long in *T. veniciae*), longer lemma lobes 0.3–2.1 mm long (1.8–3.2 mm long in *T. veniciae*), and 3–7 florets (6–15 in *T. veniciae*). *Triodia lutiteana* only occurs south of the of the Fortescue River valley, while *T. veniciae* is restricted to the north side of the Fortescue River valley.

Triodia hubbardii has narrowly lanceolate glumes and lowest lemma lobes 1.5–2.0 mm long, similar to *T. lutiteana*. However *T. hubbardii* has leaf sheaths glabrous or at most sparsely hairy between ribs (densely woolly on submargins in *T. lutiteana*), rachilla internodes flattened and with a median rib (terete to slightly compressed in *T. lutiteana*), palea body indurated and keels winged (palea membranous-chartaceous and not winged or with a very narrow wing to 0.1 mm wide in *T. lutiteana*), florets 5–12 (3–7 in *T. lutiteana*), and is disjunct from *T. lutiteana* in rocky hills of central Australia (Lazarides 1997; Lazarides *et al*. 2005).

Three species of Pilbara *Triodia* are now known only from shale: *T. lutiteana*, *T. mallota* B.M.Anderson & M.D.Barrett (Anderson *et al*. 2017a), and *T. veniciae* (Barrett 2019). *Triodia mallota* differs from *T. lutiteana* in most characters, especially in having shorter, non-resinous leaf blades, spicate inflorescences, and many-nerved glumes (Anderson 2017a; Barrett *et al.* 2017) (leaves longer, resinous, inflorescences paniculate, glumes 3–5-nerved in *T. lutiteana*).

Phylogenetic trees of ITS and ETS data (M.D. Barrett, unpublished data) indicate *T. karijini* and *T. pisoliticola* are the closest relatives of *T. lutiteana*. *Triodia pisoliticola* is distinct among these species in having awned lemmas (versus not awned) and consistently non-resinous foliage (versus conspicuously or variably resinous), but otherwise is morphologically similar. Phylogenies from ITS and ETS data place *T. veniciae* in a distant clade, with *T. bynoei* (M.D. Barrett, unpublished data).

At least one population appears fixed at a high ploidy level (hexaploid or octoploid), as discussed above, suggesting *Triodia lutiteana* may have a polyploid origin.

The vernacular name Woolly Shale Spinifex is suggested.

Co-occurring species. Grows in open woodland of *Eucalyptus leucophloia* subsp. *leucophloia* and/or *E. pilbarensis* open shrublands with *Acacia atkinsiana*, *Acacia marramamba*, *Dampiera dentata*, *Grevillea saxicola* and/or *Petalostylis labicheoies*, or in hummock grassland with *T. lutiteana* dominating or mixed with *T. wiseana* and other species. Co-occurring *Triodia* species are *T. epactia* and *T. wiseana*, and less commonly *T. angusta* and *T. longiceps*.

Triodia schinzii (Henrard) Lazarides, *Austral. Syst. Bot*. 10: 474 (1997).

Plectrachne schinzii Henrard, *Vierleljahrsschr. Naturf Ges. Zürich* 74: 134 (1929).

Type: AUSTRALIA: North Territory, prope Lander Creek, 14 June 1911, *G.F. Hill* 344 (holo: Z 000018542 *n.v.*; iso: BRI AQ0340008 image, K 000912342 [as *G.F. Hill* s.n.] image MEL 725882, PERTH 03912108 [photo of MEL isotype], US 00140959).

Plectrachne helmsii C.E.Hubb., *Bull. Misc. Inform. Kew* 1941(1): 29–30 (1941), *syn. nov*.; *Triodia helmsii* (C.E.Hubb.) Lazarides, *Austral. Syst. Bot.* 10: 434 (1997), *syn. nov. Type*: Mt Illillinna, Everard Ra., S.A., Elder Exploring Expedition, Camp 4, 8 June 1891, *R. Helms s.n.* (*holo*: K 000912420 *n.v.* (photo PERTH 03912094); *iso*: AD *n.v*., BRI AQ0340006, MEL 725889, NSW 330590, NSW 330591, PERTH 00388335).

Hummock-forming *perennial*, foliage resinous, not obviously stoloniferous; *hummocks* compact, 30–100(–130) cm high, 50–200 cm wide; *flowering culms* 100–160 cm high. *Vegetative culm internodes* all short (not or only slightly elongated), 0.4–6.1 cm long, and obscured by subtending foliage, pale to dark red-brown, glabrous or with sparse minute appressed hairs; aerial roots absent or obscure. *Leaf sheaths* 3.2–6.5 cm long, 2.8–5.0 mm wide near apex, glabrous, at least some resinous on each plant, green to straw, obscurely to prominently nerved; margins glabrous; margins of *orifice* truncate to shallowly rounded, with a dense fringe of hairs, the longest hairs 0.5–4.0 mm long. *Ligule* a dense fringe of hairs 0.2–1.0 mm long. *Pseudopetiole* not distinct, but with a subtly narrowed paler base lacking veins and 1.0–7.5 mm long that could be interpreted as a pseudopetiole. *Leaf blades* flattened-V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight and remaining so, scarcely recurved in older and dead leaves, 8.0–25.0 cm long (longest leaves per specimen 12.0–25.0 cm), 0.9–1.2 mm wide when rolled, unrolled leaves 1.5–3.0 mm wide, when fresh relatively soft, moderately pungent, glabrous abaxially, surface densely papillose adaxially, patchily or copiously resinous over abaxial surface, bright green when fresh, drying pale green or straw; stomatal grooves on abaxial surface confined to central part, 4 (2 either side of rounded mid-rib), equally spaced within the central zone (mid-rib space slightly wider), absent on marginal *c.* 1/3 but finely obscurely ribbed; stomatal grooves on adaxial surface 10–14 (5–7 each side of mid-rib); margins minutely scaberulous with minute prickle hairs *c.* 0.05–0.10 mm long. *Flag-leaf* sheaths 7.5–34.0 cm long, involute, glabrous; blade 1.4–4.1 cm long. *Panicle* (9.0–)12.5–30.5 cm long, 1.7–8.5 cm wide, with 25–72 spikelets total, linear to lanceolate, or ovate at anthesis, dense to moderately loose; primary axis sub-terete to angular to ribbed or flattened, glabrous except minute tufts of hairs 0.1–0.4 mm long sometimes present in branch axils, non-resinous; primary branches densely to openly racemose (or extreme base of longest branches very briefly ternate). Longest primary panicle branches 1.9–7.8 cm long with (1–)3–5 ±uniform-sized spikelets in a moderately dense to loose arrangement (adjacent glumes slightly or strongly overlapping); axis sub-terete to angular or weakly flattened with internodes between pedicels 8.0–17.0 mm long; longest *pedicels* at base of longest panicle branches (1.0–)1.4–8.5 mm long, 0.10–0.25 mm wide, the longest ones ±filiform, becoming slightly thicker and 0.25–0.45 mm diam. just below spikelet, terete to sub-angular, minutely scabrous; upper lateral pedicels on branch gradually becoming shorter than lowest one; terminal pedicel 8.0–32.0 mm long. *Spikelet* (12.0*–)14.0–26.0 mm long and 1.0–6.0 mm wide (excluding awns but including glumes), the combined florets without glumes (6.0*–)7.5–19.0 mm long (excluding awns), loosely 4–7-flowered with 3–5 fertile florets (apparently 1–3 sterile florets at apex, but these possibly immature), narrowly lanceolate to lanceolate or obtriangular, sub-terete or more usually laterally compressed at maturity; lowest rachilla internode 1.1–2.7 mm long, *c.* 0.15–0.20 mm diam., terete to depressed-terete, minutely scabrous or sparsely short-hairy; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* (12.0–)14.0–26.0 mm long, 1.5–2.4 mm wide, narrowly lanceolate, L:W (6.6*–)7.2–12.2 with apex narrowly acute to acuminate, distinctly longer than the combined florets (excluding awns), scarious, with narrow membranous margins 0.1–0.3 mm wide, with sparse to moderately dense very minute scabrosities less than 0.05 mm long over whole surface (appearing smooth without tangential lighting), (5–)7–11-nerved; mid-nerve moderately raised; lateral nerves scarcely to moderately raised; margins glabrous. *Upper glume* inserted 0.4–1.2 mm above lower glume, (12.0–)14.0–22.0 mm long, similar to and subequal to lower glume, distinctly longer than the combined florets (excluding awns). *Lemma* of basal floret (15.0*–)17.0–29.5 mm long including lobes, narrowly lanceolate to narrowly elliptic, deeply 3-lobed, 3-awned; body (4.0*–)5.2–7.0 mm long including callus, 0.80–1.25 mm wide *in situ* (without flattening), strongly bitextured (with lower part indurated and upper part membranous-chartaceous) with a sharp transverse transition line, fracturing at the transverse line in age; indurated lower part (3.2–)4.0–5.8 mm long (including callus) with moderately dense to dense appressed hairs 0.2–0.4 mm long (sometimes also with smaller hairs *c.* 0.1 mm long) over most of surface, or sometimes sparse to glabrous along a broad midline and/or with more ascending hairs in 2 rows either side of the midline, but always ±uniform on lateral faces, never clearly aligned into distinct rows on the lateral faces; membranous-chartaceous upper part united to (0.5–)1.0–2.1 mm above bitextured line, glabrous, with 9 nerves in 3 groups of 3 obscure nerves radiating into lobes and awns; mid-lobe (10–)11–28 mm long (including awn), narrow-triangular and 0.4–0.5 mm wide at base gradually narrowing into an awn, subequal or slightly narrower than lateral lobes; lateral lobes (7–)10–21 mm long (including awn), narrow-triangular at base gradually narrowing into an awn, margins with a very narrow or obsolete membranous wing; reverse face of lemma with a transverse thickened callus of tissue across the bitexture line. *Callus* of basal floret 0.8–1.7 mm long, straight, attached very obliquely, sharply acute and pungent in face view, sharply acute in profile, white-bearded all over or the midline entirely glabrous or glabrous in upper part only, with the longest hairs 0.2–0.7 mm long. *Upper lemmas* similar to but smaller than lowest lemma, and often with longer callus to 2.0 mm long. *Palea* of basal floret distinctly shorter to slightly longer than lemma body, 3.0–4.5 mm long, 0.7–1.0 mm wide, narrowly oblanceolate, 2-keeled, glabrous, when immature not bitextured, but at maturity usually prominently bitextured, but sometimes weakly or obscurely bitextured, and then with a small membranous apex, lower part 2.0–3.3 mm long and indurated, upper part 0.5–1.0 mm long and translucent-membranous or translucent-sub-chartaceous, with a ±abrupt to somewhat diffuse transverse junction between them, apex truncate, notched, erose or less often muticous, fragile-membranous and becoming erose; keels raised but not winged or sometimes with a short ambiguous wing to 0.1 mm wide formed from the lower margin of the membranous part at the angle of the junction between indurated and membranous part, margin densely scabrous; flaps *c.* 0.10–0.25 mm wide, ±equal over most of length, narrower than 1/2 width of the palea body and not overlapping, entire. Upper *paleas* similar but smaller than palea of basal floret, or sometimes entirely chartaceous, not bitextured, lacking a clear membranous apex. *Lodicules* 0.5–0.9 mm long; apex truncate, level or oblique, undulate or not, glabrous. *Anthers* 3, 2.0–3.8 mm long, exserted at maturity. *Style*s 2, 1.8–2.8 mm long. *Caryopsis* not seen. (Figures 2, 6)

Note that this description is compiled from specimens referred here to *T. schinzii s. str.*, excluding *T. avenoides,* but includes *T. helmsii sensu* Lazarides (1997) and Lazarides *et al*. (2005). Measurements indicated with an asterisk (*) are from a single outlier specimen with small spikelets, *P.K. Latz* 830.

Diagnostic features. Foliage resinous. Leaf sheaths glabrous on surfaces and margins. Leaves epistomatous, lacking stomatal grooves on the lateral margins of the abaxial surface. Glumes narrowly lanceolate, (12.0–)14.0–26.0 mm long, 1.5–2.4 mm. Lemmas 0.80–1.25 mm wide *in situ*, bitextured

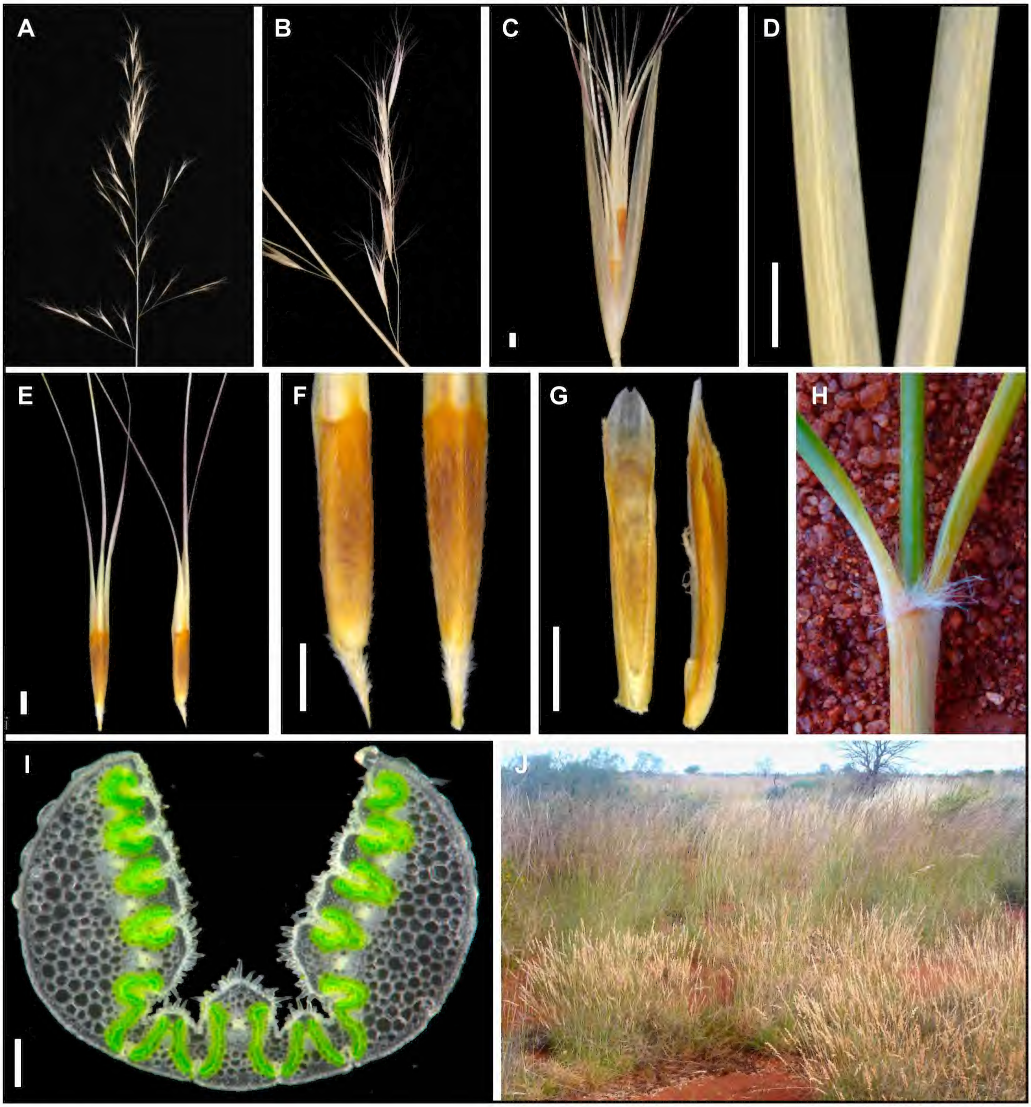

Figure 6. *Triodia schinzii*. A – inflorescence showing typical form; B – basal branches of inflorescence showing typical spikelet density; C – spikelet, showing glumes exceeding the combined florets (excluding awns); D – close-up of glumes showing multiple nerves; E – basal lemma showing relative awn and body lengths; F – lemma body in face and side view, showing appressed hairs on the indurated lower part, and a sharp transverse line demarcating the upper membranous part (lemma bitextured), and note the callus which is long-pungent, longer and sharper than that of *T. degreyensis* (*cf.* Figure 3); G – palea in face and side view, showing well-differentiated (bitextured) texture, and lack of indumentum; H – orifice of leaves showing orifice hairs, glabrous sheath faces and margins; I – leaf blade in section, showing epistomatous leaf anatomy and four abaxial stomatal grooves; J – flowering plants *in situ* (taller, finer plants in mid-ground; smaller plants in the foreground with straw-coloured inflorescences are *T. basedowii*, which commonly co-occurs with *T. schinzii*) showing habit on red sand plain. Scale bars = 1 mm (C–G); 0.2 mm (I). Images from *M.D. Barrett & W. Lewandrowski* MDB 3917 (A–G, J), *M.D. Barrett & B.M. Anderson* MDB 4072 (I), *M.D. Barrett*, *B.M. Anderson & P. Jobson* MDB 4517. Images by M.D. Barrett; images A, C, E, F, G and I modified from SpiKey (Barrett *et al.* 2017), used with permission.

with upper membranous part sharply demarcated from lower indurated part by a transverse line, indurated part appressed-hairy all over, lobes awned, callus 0.8–1.7 mm long. Palea usually bitextured, glabrous or rarely hairy, keels not winged (or at most with a short, narrow part-wing).

Selected specimens examined (of T. schinzii s. str.*)*. NORTHERN TERRITORY: 8 km East of Docker River, 15 Dec. 2000, *D.E. Albrecht* 9668 (NT); On Docker River Rd, approximately 19.4 km E of Docker River, 10 Oct. 2014, *B.M. Anderson & P. Jobson* BMA 86 (PERTH); 45 km from Aileron towards Alice Springs, 2 Oct. 2004, *M.D. Crisp* 9773 (CANB, DNA); 22 miles E of Utopia Stn, 13 May 1955, *M. Lazarides* 5276 (PERTH); 40km ESE Barrow Creek, 15 May 1996, *P.K. Latz* 14845 (MEL, NT); Winnecke Hills Soak, 40 km SW of Lajamanu, 1 May 2004, *C.P. Mangion & D.L. Lewis* 114 (PERTH). SOUTH AUSTRALIA: 3 km NE Timber Camp Bore; Perdika Desert, 23 Mar. 1999, *P.K. Latz* 15859 (AD *n.v.*, CANB, NT). WESTERN AUSTRALIA: 5 km S of Capricorn Roadhouse, 8 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3917 (PERTH); Coondiner Pool, 17 Mar. 2013, *M.D. Barrett & B.M. Anderson* MDB 4072 (PERTH, 2 sheets); 78 km NW of Marble Bar, 19 Mar. 2013, *M.D. Barrett & B.M. Anderson* MDB 4097 (PERTH); Ganthaume Point, Broome, 16 Apr. 2013, *M.D. Barrett & B.M. Anderson* MDB 4375 (DNA, PERTH, 2 sheets); 28 km SSW of Tunnel Creek Station, 9 May 2003, *D.J. Edinger & G. Marsh* DJE 3506 (PERTH); 3 km WNW of Mt Florrie, 73 km E of Warburton, Central Ranges, 28 Apr. 2001, *D.J. Edinger, B.& B. Backhouse & G. March* DJE 2312 (PERTH); 27 km SSW of Warburton, 10 May 2001, *D.J. Edinger, B. & B. Backhouse & G. Marsh* DJE 2465 (PERTH); Mindy North Mining Tenement, Newman, 23 April 2007, *T. Edwards* MN 51-01 (PERTH); Great Sandy Desert, 10 May 1979, *A.S. George* ASG 15684 (PERTH); Tobin Lake, 5 May 1979, *A.S. George* 15620 (DNA, PERTH, 2 sheets); Telfer, 3 May 2007, *P. Golos & K. Dixon* 4 (PERTH); Bungabiddy Creek, Lake Gregory, 12 June 2006, *T. Handasyde* TH 3028 (PERTH); Broome, 15 Mar. 1987, *K.F. Kenneally* 9856 (PERTH); 50 miles E of Docker River Settlement, 25 Oct. 1970, *P.K. Latz* 830 (CANB, DNA, PERTH); 3 km NW of Docker River Settlement, 24 Aug. 2007, *P.K. Latz* 22930 (NT); Rudall River, 9 Sep. 1971, *B.R. Maslin* 2195 (PERTH); 42 km E of Newman, 25 June 2007, *R. McIntyre* JB 2-22 (PERTH); 28.2 km from Weelarrana Homestead near Newman, 20 June 1996, *A.A. Mitchell* PRP 1153 (PERTH); 16.3 km from Sylvania Station Homestead near Newman, 24 June 1996, *A.A. Mitchell* PRP 1192 (PERTH); 25 km NNW of Muccan Station Homestead near Shay Gap, 20 Aug. 1997, *A.A. Mitchell* PRP 1825 (CANB, PERTH, 2 sheets); 5 km N on the Gary Hwy from the Gunbarrel Hwy, 9 June 2007, *L.S.J. Sweedman* 7081 (PERTH); Broome, 28 Aug. 2007, *Woodman Environmental Consulting* POB 03-19 (PERTH).

Specimens examined referred to T. helmsii *by M. Lazarides* (see also types cited above): NORTHERN TERRITORY: Petermann Ranges, 22 Sep. 1978, *A.C. Beauglehole* 60786 (DNA); 5 miles E of Docker River, 28 Sep. 1970, *C.R. Dunlop* 1916 (CANB, DNA). WESTERN AUSTRALIA: Petermann Ranges, 22 Sep. 1978, *A.C. Beauglehole* 60601 (CANB, DNA, MEL); Neale Junction, 10 Oct. 1966, *A.S. George* 8387 (PERTH).

Phenology. Fertile collections are mostly between March and September.

Distribution and habitat. The habitat of *T. schinzii s. str.* reported by Lazarides (1997), (excluding *T. helmsii*) is ‘plains, dunes, sandhills, swales and pindan in deep, red sands, sandy loams, clayey sands and sandy red earths; also on shallow stony soils, alluvial creek levees, coastal pindan and beach sands’ and ‘associated with sandstone, laterite, limestone and slates’. It should also be noted that the second part of Lazarides’ (1997) habitat description of *T. schinzii* [after ‘also’] probably refers to marginal or underlying geology, and the presence of rocks in the substrate are here regarded as incidental marginal habitat rather than a typical habitat, since the vast majority of plants occur on sandy substrate, only rarely sand amongst rocks (M.D.Barrett, pers. obs.). Grigg *et al*. (2008) and Grigg (2009) reported

T. schinzii at Nifty in the Great Sandy desert rooting up to 2 m deep, and occurring only on sand, compared to *T. basedowii* rooting 0.2–1.0 m, on interdunes in sandy or gravelly soil).

Conservation status. Not considered at risk.

Etymology. The epithet *schinzii* honours Hans Schinz (1858–1941), Swiss explorer and botanist.

Notes. The descriptions of *T. schinzii* in Lazarides (1997), Sharp and Simon (2002) and Lazarides *et al*. (2005) include both *T. avenoides* and *T. schinzii* as treated here. The description of *T. helmsii* in Lazarides (1997) and Lazarides *et al*. (2005) is within the variation of *T. schinzii* described here, even excluding specimens previously attributed to *T. helmsii*.

Discrimination of *T. schinzii* from other species with epistomatous leaves and awned bitextured lemmas is discussed under *T. avenoides*.

The vernacular name Feathertop Spinifex has been applied to *T. schinzii* (Lazarides 1970; Sharp & Simon 2002; Barrett *et al*. 2017).

Triodia veniciae M.D. Barrett, *Nuytsia* 30: 222–227, Figure 1 (2019).

Since the treatment of this species in Barrett *et al*. (2017) and Barrett (2019), a slightly greater range of basal lemma mid-lobe (including awnlet) has been detected, the range now being 1.8–4.5 mm long (M.D. Barrett, pers. obs.; S. Coultas & C. van der Bergh, *in litt*., 21 May 2020). Additional images of vegetative parts and leaf section, not illustrated when the species was described (Barrett 2019) are shown in Figure 7. During surveys for this species in 2017, most populations located were growing on sparsely vegetated shale slopes, and were long unburnt. A single population (unvouchered, a few km north of *M.D. Barrett* 5412) had been burnt about 2–3 years prior, and observations on the fire response could be made. Most clumps had been burnt to stumps shortly above ground level, but were resprouting (Figure 7A). Small numbers of seedlings were also observed, while no seedlings were observed in any of 13 unburnt populations. *Triodia veniciae* is therefore, at least under some conditions, predominantly resprouting and germinates episodically after fire. Fire intensity would affect the survival rate, while seedling germination and recruitment is likely rainfall-dependent.

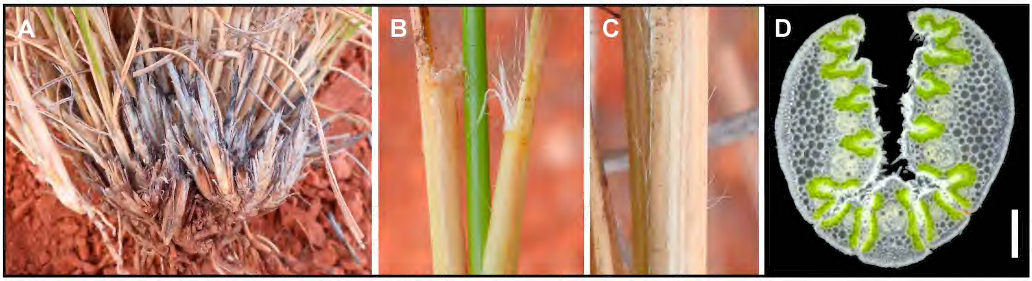

Figure 7. *Triodia veniciae*. A – base of plant burnt 2–3 years previously, showing burnt and killed culm bases on the margins, and culms that have re-sprouted post-fire in the central part; B – orifice of leaves, showing copious resin, embedding the leaf sheath hairs; C – leaf sheath indumentum, showing sparse pilose hairs that are usually present at least sparsely; D – leaf section, showing four abaxial stomatal grooves. Scale bar = 0.2 mm (D). Images from *M.D. Barrett* 5412 (B and C), and *M.D. Barrett* 5414 (D); image A is from an un-vouchered location a few km north of the location of *M.D. Barrett* 5412. Images by M.D. Barrett; images B and D modified from SpiKey (Barrett *et al*. 2017), used with permission.

Conclusions

All four species newly described here are tightly associated with specific geological substrates, highlighting an important role of niche specialisation in determining species range and intrinsic rarity in many Pilbara *Triodia*. With the species described here, the Pilbara *Triodia* flora is nearing completion, with only a single phrase-named species, *T.* sp. Mt Ella (M.T. Trudgen MET 12739), remaining without a formal name, though a full description is in Barrett and Trudgen (2018). In addition, no detailed description exists for a rare *T. longiceps* × *T. wiseana* hybrid, although features relevant to its identification are covered in Barrett *et al.* (2017). With the species described here, a total of 29 species and one hybrid are now known from the Pilbara bioregion and its immediate surrounds, more than doubling the 14 species listed from the Pilbara in the Flora of Australia treatment (Lazarides *et al*. 2005). Note that this accounting excludes three species reported by Lazarides *et al*. (2005): *T. acutispicula*, *T. bynoei* and *T. pascoeana*, which were erroneously mapped from the Pilbara based on misidentified specimens of *T. schinzii*, *T. melvillei* and *T. angusta*, respectively. If adjacent regions are included (Pilbara and Carnarvon, and western parts of Great Sandy Desert and Little Sandy Desert IBRA regions), then 14 species are endemic to this greater-Pilbara region, an endemism of 48%. Ongoing revision of some species complexes (e.g. *T. brizoides*, *T. spicata*. and *T. wiseana*) will likely further increase the endemism in the Pilbara and surrounds.

Acknowledgements

We acknowledge three sources of funding for this work. Most of the exploratory DNA sequencing and species concept development for the species treated here was completed during an Australian Research Council Linkage grant (LP120100350), including the following Partner Organisations and key personnel: The University of Western Australia (Pauline Grierson), Rio Tinto Iron Ore (in particular Trudy Worthington), Chevron Australia Pty Ltd, Botanic Gardens and Parks Authority (especially Siegy Krauss) and the (former) WA Department of Parks and Wildlife (particularly Kevin Thiele and Steven van Leeuwen). Ian Cotton and Pilbara Corridors are thanked for providing funding for the SpiKey app (Barrett *et al*. 2017), for which the descriptions of three of the species were drafted. The Pilbara Corridors Project is an initiative of Rangelands NRM, Greening Australia and the (former) WA Department of Parks and Wildlife, and supported through funding from the Australian Government. This paper was finalised with funding from the Bush Blitz Taxonomy Research Project 2020–21.

Benjamin Anderson and Wolfgang Lewandrowski provided field support during field trips in the Pilbara. Staff at the Western Australian Herbarium, in particular Karina Knight, Julia Percy-Bower, and Juliet Wege, and at the Australian National Herbarium (particularly Brendan Lepschi and Jo Palmer) are gratefully thanked for assistance with specimen processing and editorial assistance. Sam Coultas and Clinton van der Bergh are thanked for bringing additional variation in *T. veniciae* to our attention.

Biota Environmental Services was engaged to undertake the botanical surveys in the Nammuldi-Silvergrass area for Fortescue Metals Group Ltd. during which the discovery of *Triodia lutiteana* was made. They are gratefully thanked for their on-going support of research on *T. lutiteana*, and their support of the field trip where type material of the taxon was collected.

Jerome Bull from Onshore Environmental Consultants is thanked for the important collections of *Triodia karijini*. These specimens were invaluable in the recognition and subsequent description of this taxon.

A reviewer (Benjamin Anderson) provided a significant number of suggestions which greatly improved the manuscript.

References

Anderson, B.M., Barrett, M.D., Krauss, S.L. & Thiele, K. (2016). Untangling a species complex of arid zone grasses (*Triodia*) reveals patterns congruent with co-occurring animals. *Molecular Phylogenetics and Evolution* 101: 142–162. doi:10.1016/j.ympev.2016.05.014.

Anderson, B.M., Thiele, K.R. & Barrett, M.D. (2017a). A revision of the *Triodia basedowii* species complex and close relatives (Poaceae: Chloridoideae). *Australian Systematic Botany* 30: 117–229.

Anderson, B.M., Thiele, K.R., Krauss, S.L. & Barrett, M.D. (2017b). Genotyping-by-sequencing in a species complex of Australian hummock grasses (*Triodia*): methodological insights and phylogenetic resolution. *PLoS One* 12: e0171053. doi:10.1371/journal.pone.0171053.

Anderson, B.M., Thiele, K.R., Grierson, P.F., Krauss, S.L., Nevill, P.G., Small, I.D., Zhong. S. & Barrett, M.D. (2019). Recent range expansion in Australian hummock grasses (*Triodia*) inferred using genotyping-by-sequencing. *AoB PLANTS* 11: plz017. https://doi.org/10.1093/aobpla/plz017.

Armstrong, G. (2008). *Triodia caelestialis* (Triodieae: Chloridoideae: Poaceae), a new species from the central Kimberley, Western Australia. *Journal of the Royal Society of Western Australia* 91: 313–317.

Barrett M.D., Anderson B.M. & Thiele K. (2017). *SpiKey: An interactive key to Triodia spinifex grasses of the Pilbara, Western Australia*. Version 1. Identic Pty Ltd, Brisbane. http://keys.lucidcentral.org/keys/v3/triodia/.

Barrett, M.D. (2019). *Triodia veniciae* (Poaceae), a new species from the Pilbara region, Western Australia. *Nuytsia* 30: 221–228.

Barrett, M.D. & Trudgen, M.E. (2018). *Triodia pisoliticola* (Poaceae), a new species from the Pilbara region, Western Australia, and a description for *T.* sp. Mt Ella (M.E. Trudgen 12739). *Nuytsia* 29: 271–281.

Barrett, R.L., Wells, G.B. & Dixon, K.W. (2005). New taxa and combinations: Subfam. Chloridoideae, Trib. Triodieae, *Triodia*. *In*: K Mallett, (ed.). *Flora of Australia*. Vol. 44B. pp. 458–459. (CSIRO Publishing: Melbourne, Australia.)

Barrett, R.L. & Barrett, M.D. (2011). Two new species of *Triodia* (Poaceae: Triodieae) from the Kimberley region of Western Australia. *Telopea* 13: 57–67.

Barrett, R.L. & Barrett, M.D. (2015). Twenty-seven new species of vascular plants from Western Australia. *Nuytsia* 26: 21–87.

Crisp, M.D., Mant, J., Toon, A. & Cook, L.G. (2015). Australian spinifex grasses: new names in *Triodia* for *Monodia* and *Symplectrodia*. *Phytotaxa* 230: 293–296.

Department of the Environment (2013). *Australia's bioregions (IBRA)*. IBRA7, Commonwealth of Australia. http://www.environment.gov.au/land/nrs/science/ibra#ibra [accessed 15 August 2023].

Gamage, H.K., Mondal, S., Wallis, L.A., Memmott, P., Martin, D.J., Wright, B.R.& Schmidt, S. (2012). Indigenous and modern biomaterials derived from *Triodia* ("spinifex") grasslands in Australia. *Australian Journal of Botany* 60: 114–127.

Grigg, A.M., Veneklaas, E.J. & Lambers, H. (2008). Water relations and mineral nutrition of *Triodia* grasses on desert dunes and interdunes. *Australian Journal of Botany* 56: 408–421.

Grigg, A.M. (2009). *An ecophysiological approach to determine problems associated with mine-site rehabilitation: a case study in the Great Sandy Desert, north-western Australia*. PhD Thesis, University of Western Australia.

Hammer, T.A., Macintyre, P.D., Nge, F.J., Davis, R.W., Mucina, L. & Thiele, K.R. (2018). The noble and the exalted: a multidisciplinary approach to resolving a taxonomic controversy within *Ptilotus* (Amaranthaceae). *Australian Systematic Botany* 31: 262–280. https://doi.org/10.1071/SB17062.

Henrard, J.T. (1929). *Plectrachne*, a new genus of grasses. *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich* 74: 130–134.

Hubbard, C.E. (1941). Gramineae Australienses: III. *Kew Bulletin of Miscellaneous Information* 1941: 25–31.

Hurry, C.R., Walsh, N.G. & Murphy, D.J. (2012). A taxonomic review of *Triodia bunicola* and *T. scariosa* (Poaceae: Chloridoideae), based on morphological and molecular data. *Australian Systematic Botany* 25: 304–312. doi:10.1071/SB10044.

Jessup, J., Dashorst, G.R.M. & James F.M. (2006). *Grasses of South Australia: an illustrated guide to the native and naturalised species.* (Wakefield Press: Kent Town, South Australia.)

Lazarides, M. (1970). *The Grasses of Central Australia.* (Australian National University Press: Canberra.)

Lazarides, M. (1981). Gramineae. *In*: Jessop, J.P. (ed.) *Flora of Central Australia*. pp. 429–495. (A.H. and A.W. Reed Pty Ltd: Sydney.)

Lazarides, M. (1997). A revision of *Triodia* including *Plectrachne* (Poaceae, Eragrostideae, Triodiinae). *Australian Systematic Botany* 10: 381–489. doi:10.1071/SB96012.

Lazarides, M., Weiller, C. & McCusker, A. (2005). Triodia. *In*: K Mallett, (ed.). *Flora of Australia*. Vol. 44B. pp. 203–256. (CSIRO Publishing: Melbourne, Australia.)

Lee, K.K., Harrison, D.K., Johnston, M.E. & Williams, R.R. (2007). Molecular taxonomic clarification of *Ptilotus exaltatus* and *Ptilotus nobilis* (Amaranthaceae). *Australian Systematic Botany* 20: 72–81. https://doi.org/10.1071/sb06010.

Rios, E.F., Kenworthy, K.E. & Munoz, P.R. (2015). Association of phenotypic traits with ploidy and genome size in annual ryegrass. *Crop Science* 55: 2078–2090. https://doi.org/10.2135/cropsci2015.01.0039.

Sharp, D. & Simon, B.K. (2002). *AusGrass: Grasses of Australia*. CD-ROM, Version 1.0 (Australian Biological Resources Study: Canberra, and Environmental Protection Agency: Queensland.)

Thompson, E.J. (2021). A review of the classification and taxonomic and geographic distribution of cleistogamy in Australian grasses. *Australian Journal of Botany* 70: 63–101. doi:10.1071/BT20114.

Toon, A., Crisp, M.D., Gamage, H., Mant, J., Morris, D.C., Schmidt, S. & Cook, L.G. (2015). Key innovation or adaptive change? A test of leaf traits using Triodiinae in Australia. *Scientific Reports* 5: 12398.

Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Nuytsia The journal of the Western Australian Herbarium
https://florabase.dbca.wa.gov.au/nuytsia/
https://doi.org/10.58828/nuy01066
Nuytsia 34: 295–297
Published online 26 October 2023

Corrigendum to: *Marasmius australotrichotus* (Marasmiaceae), a new setose species from Australia, and an intriguing range extension for *M. paratrichotus*

Frances E. Guard[1], John Dearnaley[2], Teresa Lebel[3,4], Matt D. Barrett[5] and Neale L. Bougher[6]

[1] University of Southern Queensland, Toowoomba, Queensland 4350
[2]School of Agriculture & Environmental Science, Faculty of Health,
Engineering & Sciences, University of Southern Queensland, Toowoomba, Queensland 4350
[3]State Herbarium of South Australia, Hackney Road, Adelaide, South Australia 5000
[4]Royal Botanic Gardens Victoria, Private Bag 2000, Victoria 3141
[5]Australian Tropical Herbarium, James Cook University,
PO Box 6811, Cairns, Queensland 4870
[6]Western Australian Herbarium, Biodiversity and Conservation Science,
Department of Biodiversity, Conservation and Attractions,
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
[1]Corresponding author, email: franguard@icloud.com

SHORT COMMUNICATION

See *Nuytsia* 34: 203–219 (2023).

p. 208. 15 specimens from Table 1 are missing.

Table 1. Dataset of 53 *Marasmius* species used in the phylogenetic analysis for this study. New sequences in **bold.**

Species	Sect./Series Traditional classification	Collection#	GenBank# ITS/LSU
M. atrorubens	*Sicci/Atrorubentes*	JO528	KP635207
M. atrorubens	*Sicci/Atrorubentes*	JO489	KP635206
M. australotrichotus	***Sicci/Spinulosi***	**AMW1F**	**OQ725921**
M. australotrichotus	***Sicci/Spinulosi***	**PIF26879**	**OQ725926**
M. australotrichotus	***Sicci/Spinulosi***	**GMB-2014**	**KP012696**
M. australotrichotus	***Sicci/Spinulosi***	**SMF 3296**	**OQ725923/OQ725916**
M. australotrichotus	***Sicci/Spinulosi***	**PIF27894**	**OQ725925/OQ725917**
M. australotrichotus	***Sicci/.Spinulosi***	**F2021072**	**OQ725920/OQ725914**
M .australotrichotus	***Sicci/Spinulosi***	**Cribb-249**	**OQ725927**
M. australotrichotus	***Sicci/Spinulosi***	**MDB F2022110**	**OQ725924**
M. chrysoblepharioides	*Sicci/Spinulosi*	SI-15-24	MF683956
M. cohaerens	*Sicci/Spinulosi*	TENN 067870	KF774179

© Department of Biodiversity, Conservation and Attractions 2023
ISSN 2200-2790 (Online)
ISSN 0085-4417 (Print)

Species	Sect./Series Traditional classification	Collection#	GenBank# ITS/LSU
M. cohaerens	*Sicci/Spinulosi*	TENN 067916	KF774178
M. cohaerens	*Sicci/Spinulosi*	BRNM 695761	GU266260
M. cohaerens	*Sicci/Spinulosi*	LE295982	KF774174
M. cohaerens var. *mandshuricus*	*Sicci/Spinulosi*	LE295986	KF774171
M. cohaerens var. *lachnophyllus*	*Sicci/Spinulosi*	iNAT:16190382	MZ197975
M. corrugatiformis	*Sicci/Atrorubentes*	Buyck 97.425	KX148981
M. dendrosetosus	*Sicci/Spinulosi*	JES 205	NR158833
M. dendrosetosus	*Sicci/Spinulosi*	JES 211	KX148996
M. elegans	*Sicci/ Atrorubentes*	JAC13253	OQ282799
M. elegans	*Sicci/ Atrorubentes*	JAC10928	OQ282785
M. grandisetulosus	*Sicci/Spinulosi*	DED 8225	KX953743
M. grandisetulosus	*Sicci/Spinulosi*	DED 8257	KX953744
M. grandiviridis	*Globulares*	NW152	EU643514
M. hinnuleus	*Sicci/Haematocephali*	JES 217	KX148988
M. hypophaeus	*Sicci/Haematocephali*	NW285	EU935484
M. iras	*Sicci/Atrorubentes*	NW276	EU935486
M. iras	*Sicci/Atrorubentes*	NW375	EU935487
M. katangensis	*Sicci/Atrorubentes*	JES 227	KX148991
M. laticlavatus	*Globulares*	NW412	EU643511
M. longisetosus	*Sicci/Spinulosi*	JO248	JX424040
M. longisetosus	*Sicci/Spinulosi*	SP 417470	NR154160
M. megistus	*Sicci/Leonini*	JES 163	KX148992
M. neotrichotus	*Sicci/Spinulosi*	SI-7-13	MF683958
M. nummularius	*Sicci/Spinulosi*	NW396	EU935493
M. nummularius	*Sicci/Spinulosi*	JES121	KX148979
M. ochroleucus	*Sicci/Atrorubentes*	LE 295978	KF912952
M. orientalis	*Sicci/Spinulosi*	BRNM 714913	GU266262
M. paratrichotus	***Sicci/Spinulosi***	**NLB 1255**	**ON715786**
M. paratrichotus	***Sicci/Spinulosi***	**MDB F26/03**	**OQ725928**
M. paratrichotus	*Sicci/Spinulosi*	DED 8248	KX953749
M. purpureostriatus	*Globulares*	BRNM 714566	FJ904978
M. torquescens	*Sicci/Spinulosi*	BRNM 691427	GU266258
M. aff. trichotus	*Sicci/Spinulosi*	AKD 05/2015	MF189039
M. aff. trichotus	*Sicci/Spinulosi*	AKD 06/2015	MF189040
M. trichotus	*Sicci/Spinulosi*	NW263	EU935491
M. trichotus	*Sicci/Spinulosi*	NW262	EU935490
M. trichotus	*Sicci/Spinulosi*	NW1341	MW426437
M. vagus	*Sicci/Leonini*	SMF 3041	MT117839

Species	Sect./Series Traditional classification	Collection#	GenBank# ITS/LSU
M. vagus	*Sicci/Leonini*	F2020016	MT117841
M. xestocephalus	*Sicci/Atrorubentes*	NW344	EU935489
M. xestocephalus	*Sicci/Atrorubentes*	JFK69	EU935488

Referees for Volume 34

The assistance of referees in providing expert review of papers submitted to *Nuytsia* is gratefully acknowledged. The referees consulted for Volume 34 include those listed below and 3 anonymous reviewers. Each paper was also refereed internally by *Nuytsia* Editorial Committee members.

Benjamin Anderson
Bob Chinnock
Alex George
Stephen Hopper
Teresa Lebel
Terry Macfarlane
Bruce Maslin
Tom May
Peter Olde
David Orlovich
Hana Ševčíková
Lindsay Shelton
Heroen Verbruggen
Annette Wilson

Nuytsia 34 (2023)

ISSN 0085-4417
Print Post approved PP665002/00003